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T H E U N I V E R S I T Y O F M I C H I G A N

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Abstract

The MAD/I language is a procedure-oriented algebraic language which is a descendant of ALGOL 60 and 7090 MAD, similar in power and scope to PL/I. The MAD/I compiler is implemented using the MAD/I facility, a flexible translator-building system whose dynamic nature allows compilers to be extended during the compilation process. This paper demonstrates the extension of MAD/I to include several graphics-oriented statements and operators through a lucid example.

1. INTRODUCTION

The MAD/I project of the University of Michigan has designed and implemented a flexible translator-building system called the MAD/I facility. The facility provides services to aid in the lexical and syntactic scanning [3] of the program, storage allocation, and object-code generation. A compiler is written in the facility as a set of procedures, called a macro, to which is control passed at various times by the syntactic scanner and by the contents of the intermediate storage of the partially compiled programs. New macros can be redefined while a compiler is executing, thus making extensions to the compiler (and hence to the language) possible.

A compiler, called the MAD/I compiler, has been implemented using the MAD/I facility. The language accepted by the MAD/I compiler is called the MAD/I language [1]. The MAD/I language is a procedure-oriented algebraic language which is a descendant of ALGOL 60 and 7090 MAD, similar in power and scope to PL/I. Because the MAD/I compiler is written in the MAD/I facility, there is a great potential for extensibility features within the MAD/I language. To date, no extension facilities have been designed for the MAD/I language; that is properly a goal of further research.

This report presents an example definitional facility in the MAD/I language. A simple list-processing program is written in the MAD/I language as extended to include three

new modes, three new statements, and eight new operators. These extensions are written using the macro language of the MAD/I facility and two experimental definitional statements. These definitional statements, or similar ones determined to be more appropriate, could easily be incorporated as a part of the MAD/I language. For the moment, they also are defined at compile-time.

The remainder of this report explains in detail the simple program and the code necessary to define the language extensions. This explanation references the computer output which appears at the end of the report. This output consists of six parts:

(1) a listing of the contents of the file SKETCH which is the sample MAD/I program,

(2) a listing of the contents of the DISPLAYDEF which defines the extensions fo the MAD/I language,

(3) a listing of the contents of the file DEFFACILITY which defines the two experimental statements,

(4) a listing of the contents of the file -DATA which contains the data used in the run of Step (6),

(5) the compilation of the MAD/I program, and

(6) the run of the generated object program using the data of Step (4).

The object-code listing of the compilation has been removed to reduce the bulk of the report.

2. SKETCH

The file SKETCH contains the sample MAD/I program. This program maintains a simple list structure representing points, lines, and collections of points called pictures. The list structure can be manipulated or printed through several commands which are recognized by the program. These commands are:

POINT which adds a point to the list structure. The user is prompted for the x and y coordinates of the point. The point is assigned an internal display number which is used to reference the point in other commands.

LINE which adds a line to the list structure. The user is prompted for the internal display numbers of the two endpoints of the line. The line is defined in terms of its endpoints and will be moved appropriately if its endpoints are moved.

PICTURE which groups several points together into a collection called a picture. The user is prompted for the internal display numbers of the points in the picture. Whenever one point of a picture is translated, all the points in the picture are translated.

MOVE which moves a point to new x and y coordinates. The user is prompted for the display number of

the point and its new x and y coordinates. If the point is in a picture, all other points in the picture are also translated by the same amount.

DISPLAY which prints a display of the current list structure.

This program is oriented to standard typewriter terminals, such as teletypes. It could easily be modified to interface to a remote graphics terminal using the display subroutines developed as a part of the CONCOMP Project [2].

Line 1 of SKETCH simply begins a procedure named SKETCH.

Line 3 of SKETCH includes the contents of the file DISPLAYDEF which defines the new statements, modes, and operators which will be used in this program. The contents of DISPLAYDEF will be described in the next section.

Lines 5 through 13 declare the modes of variables used in the program. Note that 'POINT', 'LINE', and 'PICTURE' are used as modes in declarations. These have been defined as described for line 3 above. Line 5 causes all variables which are not explicitly declared to receive the default mode 'INTEGER'.

Line 15 presets the number of pictures to zero.

Lines 18 and 19 prompt the user for the next command from his terminal. The first four characters of the command are stored in the variable COMMAND.

Lines 21 through 120 form a compound 'IF' statement. The subsection of this statement which corresponds to the command entered is given control.

Lines 22 through 29 are invoked by the POINT command. Note that line 25 uses the newly defined statement 'CREATE POINT' to create a point having the values of X and Y as its coordinates. X and Y, although shown here as simple variables, can be general expressions. The operator .DISPN., which accesses the internal display number from a point, is used in line 26 to print the display number to the user.

Lines 32 through 39 are invoked by the LINE command. The operator .ADROF. used on line 34 converts an internal display number to a 'POINTER' to the corresponding list structure item. The operator .EVAL. also used on line 34 sets the storage allocation of a based variable to the value of a variable of 'POINTER' mode. In this case P1 and P2 are allocated to the list structure items corresponding to the two endpoints. .EVAL. is a built-in MAD/I operator whose name has since been changed to .ALLOC.. The operator .POINT. used

in line 35 returns a value of 'TRUE' if its operand is a list structure item corresponding to a point; 'FALSE' otherwise. Note that line 36 uses the new statement 'CREATE LINE' to create the line whose endpoints are P1 and P2.

Lines 42 through 57 are invoked by the PICTURE command. PICTURE is an array of up to 100 pictures, each element being the head of a linked ring of points in the picture. PICTUREN is the number of pictures allocated thus far. Lines 43 through 47 increment the number of pictures thus far, test to see that less than 100 pictures have been formed, and initialize the current picture to the empty set. The O.AS.('POINTER') of line 47 is the empty picture constant and would better have been written O.AS.('PICTURE'). As we will see later, 'PICTURE' has been defined as a synonym for 'POINTER' which explains why the former case works. Lines 48 through 55 are executed once for each point in the picture. Lines 50 and 51 access the list structure item corresponding to the next point to be coded to the picture and test that is a point. Lines 52 through 54 insert the point into the picture using the 'CONNECT' statement. A restriction in the implementation of our experimental define statement facility prevents us from rewriting these three statements as the one statement

'CONNECT' P1 'TO' PICTURE(PICTUREN)

Lines 60 through 75 are invoked by the MOVE command. Line 64 computes the difference between the new coordinates of the point and the old coordinates of the point. The two operators .XOF. and .YOF. access the x and y coordinates respectively of a point. Line 65 modifies the coordinates of the point to their new values. Note that .XOF. and .YOF. can be used on the left-hand side of an assignment as they return a reference. Lines 66 and 67 test if the point is a member of a picture. If the point is in a picture, line 68 accesses the next point in the picture, and lines 69 through 73 are executed for each point in the picture until we return to the original point. The .NEXT. operator returns a 'POINTER' result which points to the list structure item representing the next point in the same picture as its operand.

Lines 77 through 116 are invoked by the DISPLAY command. This code runs through the entire list structure and generates points and lines as sets of asterisks in the array DISPLAY. This array is then printed to give a visual depiction of the display on a type-writer-like terminal. Note that the variable HEAD referenced in line 83 is a 'POINTER' to the first item in the list-structure. The operator .HEAD. referenced in line 109 returns a 'POINTER' to the

list structure element which follows its operand.

This operator is used to traverse the list structure.

Line 119 is invoked if the command was not recognizable based on its first four characters.

Line 122 transfers control back to line 18 where the user is prompted for the next command.

The remainder of the program consists of two small procedures for computing the minimum and maximum of two values.

3. DISPLAYDEF

The file DISPLAYDEF contains the definitions for the extensions to the MAD/I language used in the preceding program. In actual practice, packages of definitions such as this would be written and used in programs much as subroutines are written and used in programs at present. Generally useful definitional packages would be provided by system programmers for general use just as subroutine libraries are now provided.

Lines 18 through 20 define the mode 'POINT' which is simply a synonym for a based component structure. The components are used as described in lines 11 through 16.

Lines 35 through 37 define the mode 'LINE' which is simply a synonym for a based component structure. The components are used as described in lines 28 through 33.

Line 43 defines the new mode 'PICTURE' which is simply a synonym for 'POINTER'.

Lines 48 through 52 declare and preset the variables which are used by the various statements and operators of the definitional package.

Line 56 includes the contents of the file DEFFACILITY which defines the two experimental definitional statements which are used below. The contents of DEFFACILITY will be described in the next section.

Lines 64 through 74 define the statement 'CREATE POINT' using the experimental definitional statement 'DEFINE STATEMENT'. The 'DEFINE STATEMENT' facility allows a new statement to be defined in terms of other MAD/I statements. The 'CREATE POINT' statement consists of the keyword 'CREATE POINT' followed by three expressions which correspond to the identifiers POINT, X, and Y. These three expressions will be evaluated. Then the MAD/I statements in the definition will be executed, with the results of the three expressions being substituted for each occurrence of POINT, X, and Y. Line 65 allocates a block of storage to the expression corresponding to POINT, which must be a reference to a variable of 'POINT' mode. Line 66 and 68 insert this new point into the chain of all items in the list structure. Line 68 initializes the point as <u>not</u> being an element of any picture. Lines 69 and 70 assign the next internal display number to this point. In an application using a remote display this would be an identification number for the element in the remote display program so that light-pen detects could be mapped back to the data structure in the machine in which this program is running. Line 71

sets the display item type to 1, indicating that this is a point. Lines 72 and 73 set the x and y coordinates of the point.

Lines 82 through 92 define the statement 'CREATE LINE'. This definition is similar to that used to define the 'CREATE POINT' statement above and won't be discussed further.

Line 100 defines the keyword 'TO' to be syntactically equivalent to the comma (,). This will allow us to write 'CONNECT' A 'TO' B rather than 'CONNECT' A,B. Note that this definition is done using the experimental 'DECLARE SYNTACTIC CLASS' statement.

Lines 101 through 111 define the 'CONNECT' statement. This definition is also made using the experimental definitional statement 'DEFINE STATEMENT'. Lines 104 and 105 are executed if the second point is already a member of a picture. In this case the new point is inserted into the existing ring.

Lines 116 through 124 define the operator .POINT. which returns 'TRUE' if its operand is a point, 'FALSE' otherwise. This definition is written using the macro language of the MAD/I facility and requires some explanation. If .POINT. A is written we really want to transform that into A(4)=1, a test of whether the type component of A is equal to 1. Now .POINT. A will be converted by the

syntactic scanner into the triple:

.POINT.,%TMP,A

where %TMP is an internally generated temporary symbol which represents the result of the operation. Now A(4)=1 would be converted by the syntactic scanner into the two triples:

.TAG.,%TMP1,A,4

=,%TMP2,%TMP1,1

where %TMP2 is the result of the expression. Now, if we define a macro whose name is .POINT., it will be called by the syntactic scanner with two operands, the temporary assigned and the operand. This macro can in turn generate the two triples that A(4)=1 would have generated. Line 116 declares .POINT. to be syntactically equivalent to .ABS.; that is, a unary operator with the same left and right precedence values as .ABS.. Line 117 declares to the compiler that what follows are to be considered as statements directed to the MAD/I facility. Lines 118 through 123 define the macro whose name is .POINT. and whose two operands (parameters) are given the names T and B. All identifiers in a macro definition, unless preceded by a %, are different identifiers than those of the same name in the MAD/I program. Likewise, all constants referenced in a macro definition, unless

preceded by 'LOCAL LITERAL', are self-defining constants rather than literal constants within the MAD/I program. Line 119 declares U to be a local symbol within this macro. This is roughly equivalent to automatic variables in higher-level languages. Line 120 calls the macro TEMPORARY which assigns a temporary symbol and causes U to become a synonym for the temporary. This temporary will be used as the result of the = operator. The macro TEMPORARY is defined in the next section. Line 121 generates the triple

```
.TAG., U,B,4
```

where U is the temporary result and B is the operand of the .POINT. operator. The 'LOCAL LITERAL' keyword is required so that the symbol 4 represents the MAD/I constant value 4 rather than a self-defining term 4 in the MAD/I facility. Likewise line 122 generates the triple

```
=,T,U,1
```

where T is the temporary result of the .POINT. operator which has been passed as a parameter and U is the result of the .TAG. operation generated by the preceding line. The LN is necessary preceding the "=" to indicate that this is the MAD/I operator "=" rather than the MAD/I facility

operator "=". These two triples generated are the two we have previously discussed as being equivalent to A(4)=1. Line 124 exits from the MAD/I facility. Further lines are interpreted as being a part of the MAD/I program being compiled.

Lines 129 through 186 define the operators .XOF., .YOF., .NEXT.,.DISPN.,.ENDA.,.ENDB., and .HEAD. in a manner similar to the definition of .POINT. discussed above. In each case the expression involving the operator, say .XOF.A, is to be mapped into an instance of subscription such as A(5). The operators differ only in the value of the subscript used. In each case the triple resulting from the syntactic scanning of the former case,

.XOF. ,%TMP,A

is translated into the triple which would result from the syntactic scanning of the latter case,

.TAG.,%TMP,A,5

In each case the operator is declared to be syntactically equivalent to .ABS. through the 'DECLARE SYNTACTIC CLASS' statement and is semantically defined through a very simple macro which generates the corresponding .TAG. triple.

Lines 196 through 214 define the operator .ADROF. which returns the .POINTER' to the list-structure element

which has been assigned the value of its operand as its internal display number. The .ADROF. operator could be represented in MAD/I by lines 190 through 194, However, we have not yet implemented a statement which allows operators to be defined in terms of MAD/I statements. Instead, we have implemented the .ADROF. operator as a macro which generates the same triples as would be generated by the MAD/I statements shown. Line 199 defines B1 and B2 to be local symbols. These will be used for the labels required. Lines 200 and 201 assign temporaries to T1 through T5. Line 202 calls the FLAD macro which assigns two floating addresses and makes B1 and B2 synonyms for these two floating addresses. The macro is defined in the next section. Line 203 is equivalent to the MAD/I statement of line 190. Lines 204 through 207 are equivalent to the MAD/I statement of line 191. Line 204 allocates the floating address B1 to the current value of the instruction location counter. Lines 205 and 206 compute the Boolean expression

.DISPN. QQSV = A

while line 207 transfers to B2 if the expression result is 'TRUE'. Lines 208 and 209 are equivalent to the MAD/I statement of line 192. Line 210 is equivalent to the MAD/I statement of line 193. Lines 211 and 212 are equivalent to the intended effect of the MAD/I statement of line 194 which is to return a pointer to QQSV as the result of the operator. Line 211 allocates the floating

address B2 to the current value of the instruction location counter while line 212 computes the pointer to QQSV assigning the result to T, the temporary assigned by the syntactic scanner as the result of .ADROF..

4. DEFFACILITY

The file DEFFACILITY contains the definitions of the 'DECLARE SYNTACTIC CLASS' and 'DEFINE STATEMENT' statements and the FLAD and TEMPORARY macros. Other macros have also been defined or redefined as required to implement the above. The macros used to define these statements are much more complicated than the macros used in the preceding section and require a detailed knowledge of the MAD/I facility and MAD/I compiler in order to implement them successfully. We stress that users of MAD/I will not be required to learn this detail, as appropriate higher-level definitional statements such as 'DECLARE STATEMENT' will be provided for them; only the system programmer assigned to MAD/I need to know these details.

Lines 10 through 27 define the 'DECLARE SYNTACTIC CLASS' statement. Line 11 causes 'DECLARE SYNTACTIC CLASS' to be considered syntactically a keyword which begins a simple statement. The macro named 'DECLARE SYNTACTIC CLASS' will be called by the syntactic scanner whenever the keyword is encountered in the MAD/I program. Lines 12 through 26 define the macro 'DECLARE SYNTACTIC CLASS'. Lines 14 and 15 scan off the next symbol and insert a pointer to its symbol table entry into the local symbol A. Lines 16 through 19 scan off the next symbol and

verify that it is 'SAME AS'. Line 20 scans off the next symbol which is the one having the desired syntactic qualities. Lines 21 through 24 set the syntactic attributes in the symbol table entry of the symbol being declared to the same values as on the symbol already having the desired syntactic class. Line 25 scans off the statement terminator so that we are ready to return to the syntactic scanner.

Lines 49 through 100 define the statement 'DEFINE STATEMENT'. Lines 52 through 99 define the macro 'DEFINE STATEMENT' which is called by the syntactic scanner whenever the keyword 'DEFINE STATEMENT' is encountered. This macro scans the entire 'DEFINE STATEMENT' statement scope, saving its contents as a list of symbol table pointers. It then creates a macro (lines 81 through 97) which has as its name the keyword identifying the statement being defined. This new macro is called by the syntactic scanner whenever its namesake keyword is found in the input stream. It then will call the syntactic scanner once for each expression which is a part of the statement, modify the lexical scanner (GETDSK) to return the symbol table pointers on the list formed above before continuing with

the standard input text, and call the syntactic scanner asking it to scan the scope of a compound statement. This scope, of course, consists of the statements which define the new statement saved on the list given to the lexical scanner.

Lines 108 through 126 define a macro named GETDSX. This macro will be called instead of the pseudo-operation GETDSX, which itself is the entry-point to the lexical scanner. This new macro will normally simply call the pseudo-operation GETDSX to lexically scan for the next symbol in the input stream. However, if it is passed a list of symbol table pointers via the global symbol GTDSXLIST from a macro defining a new statement, it will return the symbols from the list until the list is exhausted.

Lines 131 through 144 define the macro FLAD which generates new floating address symbols. This macro is referenced by the .ADROF. macro from the preceding section.

Lines 148 through 161 define the macro TEMPORARY which assigns new temporary result symbols. This macro is referenced by several macros in the preceding section.

Lines 167 through 223 re-define the macros GETTEMP and FREETEMP to remove deficiencies in their original

implementation in the MAD/I compiler. These macros have since been changed in the compiler so that this update is no longer necessary.

5. -DATA

The file -DATA contains the data presented to the MAD/I program in the run of Section 7. The program is intended to be used from a terminal on a conversational manner. Running the program in batch has required us to anticipate the requests for input and the assignment of internal display numbers. The reader will find it helpful to look at the printed output from the run with this data (Section 7) while reading Section 5.

Line 1 requests a display of the current contents of the list-structure. Since the list-structure is empty the comment "NOTHING TO DISPLAY." is printed.

Lines 2 through 9 define four points having coordinates (10,10),(10,40),(40,10) and (40,40). These points are assigned internal display numbers 1,2,3, and 4, respectively. Line 10 requests the current list-structure to be displayed, resulting in the first graph showing the four points.

Lines 11 through 18 connect the four points with lines forming a square. Line 19 requests the current list-structure to be displayed, resulting in the second graph showing the square.(This looks like a rectangle because the horizontal scale is 10 characters/inch while the vertical scale

is 6 characters/inch (before reduction)).

Lines 20 and 21 move the first point from its original position of (10,10) to the new position (15,20). Since this point is not a member of any picture, it is the only point moved. Line 22 displays the third graph showing the point moved to its new location.

Lines 23 through 28 mark the four points as members of the same picture. Lines 29 and 30 move the first point from its current position of (15,20) to the new position (20,20). The second, third, and fourth points are also translated horizontally by five raster units because they are members of the same picture as the first point. Line 31 causes the display of the fourth graph which shows the results of this translation.

6. COMPILATION OF THE MAD/I PROGRAM

The fifth listing is the printed output resulting from the compilation of the MAD/I program. This output begins with a listing of the source program. Notice that the contents of the files DISPLAYDEF and DEFFACILITY are included at the points where the 'INCLUDE' statements are encountered. Following the source program listing is the output of the storage allocation phase, giving the storage allocated to each variable and constant in the program. Following that is a dictionary giving the attributes of each variable and constant. Following that are the external symbol dictionary, relocation dictionary, and statistics for the compilation. The object listing has been left out because of its size (about 40 printed pages).

7. RUN OF THE MAD/I PROGRAM

The last listing is the printed output resulting from a run of the generated object module. This listing consists of the loading map followed by the printed output from the program. See Section 5 for an annotation of the output from the run.

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Appendix A. Contents of File SKETCH

```
$LIST SKETCH
     1                'PROCEDURE' SKETCH.;
     2
     3                'INCLUDE' "DISPLAYDEF"
     4
     5                'DECLARE' 'NORMAL MODE' 'INTEGER';
     6                'DECLARE' COMMAND 'CHARACTER'(4);
     7                'DECLARE' DISPLAY 'FIXED ARRAY'(50,50) 'CHARACTER'(1);
     8                'DECLARE' (POINT,P1,P2,P3) 'POINT';
     9                'DECLARE' LINE 'LINE';
    10                'DECLARE' PICTURE 'FIXED ARRAY'(100) 'PICTURE';
    11                'DECLARE' QQ1 'POINTER';
    12                'DECLARE' QQ2 'POINTER';
    13                'DECLARE' (M,M1,M2) 'FLOATING';
    14
    15                'PRESET' PICTUREN := 0;
    16
    17
    18      SKETCH:   'WRITE' , "'ENTER A COMMAND PLEASE.'*";
    19                'READ' , "C4.4*" , COMMAND;
    20
    21                'IF' COMMAND = "POIN";
    22                     'WRITE' , "' ENTER X AND Y COORDINATES:'*";
    23                     'READ' , "2I*", X,Y;
    24                     'IF' 1 <= X & 50 >= X & 1 <= Y & 50 >= Y;
    25                          'CREATE POINT' POINT,X,Y;
    26                          'WRITE' , "' ASSIGNED DISPLAY NUMBER',HI4*", .DISPN. POINT;
    27                     'ELSE';
    28                          'WRITE' , "' POINT IS OUTSIDE RASTER RANGE.'*";
    29                     'END';
    30
    31                'OR IF' COMMAND = "LINE";
    32                     'WRITE' , "' ENTER DISPLAY NUMBERS FOR END-POINTS:'*";
    33                     'READ' , "2I*", X,Y;
    34                     P1 .EVAL. .ADROF. X; P2 .EVAL. .ADROF. Y;
    35                     'IF' .POINT. P1 & .POINT. P2;
    36                          'CREATE LINE' LINE,P1,P2;
    37                     'ELSE';
    38      NOTPOINT:           'WRITE' , "' THOSE ARE NOT POINTS.'*";
    39                     'END';
    40
    41                'OR IF' COMMAND = "PICT";
    42                     'WRITE' , "' ENTER DISPLAY NUMBERS FOR ALL POINTS.'*";
    43                     PICTUREN := PICTUREN+1;
    44                     'IF' PICTUREN > 100;
    45                          'WRITE' , "' TOO MANY PICTURES.'*";
    46                     'ELSE';
    47                          PICTURE(PICTUREN) := 0 .AS. ('POINTER');
    48      PICTA:              'READ' , "I*", X;
    49                          'IF' X¬= 0;
    50                               P1 .EVAL. .ADROF. X;
    51                               'IF' ¬.POINT. P1, 'GO TO' NOTPOINT;
    52                               QQ2 := PICTURE(PICTUREN);
    53                               'CONNECT' P1 'TO' QQ2;
    54                               PICTURE(PICTUREN) := QQ2;
    55                               'GO TO' PICTA;
    56                          'END'
    57                     'END';
    58
```

```
59              'OR IF' COMMAND = "MOVE";
60                   'WRITE' , "' ENTER DISPLAY NUMBER OF POINT AND NEW X,Y'*";
61                   'READ' , "3I*", DIS,X,Y;
62                   P1 .EVAL. .ADROF. DIS;
63                   'IF' ¬.POINT. P1, 'GOTO' NOTPOINT;
64                   DX := X-.XOF. P1; DY := Y-.YOF. P1;
65                   (.XOF. P1) := .XOF. P1+DX; (.YOF. P1) := .YOF. P1+DY;
66                   QQ1 := P1(2);
67                   'IF' QQ1 .AS. ('INTEGER') ¬= 0;
68                        P2 .EVAL. .NEXT. P1;
69        MOVEA:          'IF' .DISPN. P1 ¬= .DISPN. P2;
70                             (.XOF. P2) := .XOF. P2+DX; (.YOF. P2) := .YOF. P2
71                                                            +DY;
72                             P2 .EVAL. .NEXT. P2;
73                             'GO TO' MOVEA;
74                        'END'
75                   'END';
76
77              'OR IF' COMMAND = "DISP";
78                   'IF' HEAD .AS. ('INTEGER') = 0;
79                        'WRITE' , "' NOTHING TO DISPLAY.'*";
80                        'GO TO' SKETCH;
81                   'END';
82                   'FOR' I := 1,1,I>50, 'FOR' J := 1,1,J>50, DISPLAY(I,J) := " ";
83                   P1 .EVAL. HEAD;
84        DISPA:     ;
85                   'IF' .POINT. P1;
86                        Q1 := .XOF. P1; Q2 := .YOF. P1; DISPLAY(Q2,Q1) := "*";
87                   'ELSE';
88                        LINE .EVAL. (.PT. P1);
89                        QQ1 := .ENDA. LINE; P2 .EVAL. QQ1;
90                        QQ1 := .ENDB. LINE; P3 .EVAL. QQ1;
91                        X1 := MIN.(.XOF. P2,.XOF. P3);
92                        X2 := MAX.(.XOF. P2,.XOF. P3);
93                        'IF' X1 = X2;
94                             Y1 := MIN.(.YOF. P2,.YOF. P3);
95                             Y2 := MAX.(.YOF. P2,.YOF. P3);
96                             'FOR' Y := Y1,1, Y > Y2, DISPLAY(Y,X1) := "*";
97                        'ELSE';
98                             M1 := .YOF. P3 - .YOF. P2;
99                             M2 := .XOF. P3 - .XOF. P2;
100                            M := M1/M2;
101                            'FOR' X := X1,1,X > X2;
102                                 Q2 := M*(X - .XOF. P2) + .YOF. P2;
103                                 DISPLAY(Q2,X) := "*";
104                            'END';
105                       'END';
106                  'END';
107                  QQ1 := .HEAD. P1;
108                  'IF' QQ1 .AS. ('INTEGER') ¬= 0;
109                       P1 .EVAL. .HEAD. P1;
110                       'GO TO' DISPA;
111                  'END';
112                  'WRITE' , "'1   .',10('    .')*";
113                  'FOR' I := 50,-1, I < 1,
114                       'WRITE' , "I3,52C1.1*", I," ",".",
115                                                DISPLAY(I,1)...DISPLAY(I,50);
116                  'WRITE' , "'    .',10('    .')*";
117
118             'ELSE';
```

```
    119                 'WRITE' , '' ILLEGAL COMMAND'*';
    120             'END';
    121
    122             'GO TO' SKETCH;
    123
    124             'PROCEDURE' MIN.(X,Y);
    125             'INTEGER SHORT' (X,Y);
    126     MIN:    'IF' X <= Y, 'RETURN' X;
    127             'RETURN' Y;
    128             'END';
    129
    130             'PROCEDURE' MAX.(A,B);
    131             'INTEGER SHORT' (A,B);
    132     MAX:    'IF' A >= B, 'RETURN' A;
    133             'RETURN' B;
    134             'END';
    135
    136             'END'
END OF FILE
```

Appendix B. Contents of File DISPLAYDEF

```
LIST DISPLAYDEF
    1     <<
    2                     DISPLAY DEFINITIONAL PACKAGE
    3
    4           THE FOLLOWING PARAMETER STATEMENT DEFINES THE COMPONENT STRUCTURE
    5           FOR A POINT.  THE USER SIMPLY USES 'POINT' AS A MODE NAME IN
    6           EITHER A 'DECLARE' STATEMENT OR AN @ CONSTRUCTION.  NOTE THAT
    7           THE STATEMENT
    8                     'POINT' IVARIABLE LIST)
    9           WILL NOT WORK BECAUSE THIS IS SIMPLY A PARAMETRIC SUBSTITUTION.
   10           THE STRUCTURE OF A POINT IS
   11                     1    POINTER         POINTER TO NEXT LIST ITEM
   12                     2    POINTER         POINTER TO NEXT ITEM IN SAME PICTURE
   13                     3    INTEGER SHORT   DISPLAY ITEM NUMBER
   14                     4    INTEGER SHORT   DISPLAY ITEM TYPE (1 FOR A POINT)
   15                     5    INTEGER SHORT   X COORDINATE OF THE POINT
   16                     6    INTEGER SHORT   Y COORDINATE OF THE POINT
   17    >>
   18           'PARAMETER' 'POINT' 'BASED' 'COMPONENT STRUCTURE'('POINTER',
   19                'POINTER','INTEGER SHORT','INTEGER SHORT','INTEGER SHORT',
   20                'INTEGER SHORT') 'ENDP'
   21    <<
   22           THE FOLLOWING PARAMETER STATEMENT DEFINES THE COMPONENT STRUCTURE
   23           FOR A LINE.  THE USER SIMPLY USES 'LINE' AS A MODE NAME IN EITHER A
   24           'DECLARE' STATEMENT OR AN @ CONSTRUCTION.  NOTE THAT THE STATEMENT
   25                     'LINE' IVARIABLE LIST)
   26           WILL NOT WORK BECAUSE THIS IS SIMPLY A PARAMETRIC SUBSTITUITION.
   27           THE STRUCTURE OF A LINE IS
   28                     1    POINTER         POINTER TO THE NEXT LIST ITEM
   29                     2    POINTER         POINTER TO THE NEXT ITEM IN THE PICTURE
   30                     3    INTEGER SHORT   DISPLAY ITEM NUMBER
   31                     4    INTEGER SHORT   DISPLAY ITEM TYPE (2 FOR A LINE)
   32                     5    POINTER         POINTER TO FIRST END-POINT
   33                     6    POINTER         POINTER TO SECOND END-POINT
   34    >>
   35           'PARAMETER' 'LINE' 'BASED' 'COMPONENT STRUCTURE'('POINTER',
   36                'POINTER','INTEGER SHORT','INTEGER SHORT','POINTER',
   37                'POINTER') 'ENDP'
   38    <<
   39           THE FOLLOWING PARAMETER STATEMENT DEFINES THE MODE OF A PICTURE.
   40           A PICTURE IS A POINTER TO ONE OF THE ITEMS IN THE PICTURE.  HENCE
   41           IT IS SIMPLY PARAMETERIZED TO 'POINTER' MODE.
   42    >>
   43           'PARAMETER' 'PICTURE' 'POINTER' 'ENDP'
   44    <<
   45           THE FOLLOWING STATEMENTS DEFINE THE GLOBAL VARIABLES USED BY
   46           THE DEFINITION PACKAGE.
   47    >>
   48           'DECLARE' DISPLAYN 'INTEGER SHORT';
   49           'PRESET' DISPLAYN := 0;
   50           'DECLARE' GOSV 'POINT';
   51           'DECLARE' HEAD 'POINTER';
   52           'PRESET' HEAD := 0;
   53    <<
   54           THE FOLLOWING BRINGS IN THE DEFINE FACILITY FROM THE FILE DEFFACILITY
   55    >>
   56           'INCLUDE' "DEFFACILITY"
   57    <<
   58           THE FOLLOWING DEFINES THE STATEMENT
```

```
59
60                'CREATE POINT' POINT,X,Y
61
62              WHICH HAS THE EFFECT OF THE LIST OF STATEMENTS SHOWN
63        >>
64              'DEFINE STATEMENT' 'CREATE POINT' POINT,X,Y;
65                   'ALLOCATE' POINT;
66                   POINT(1) := HEAD;
67                   HEAD := .PT. POINT;
68                   POINT(2) := (0 .AS. ('POINTER'));
69                   DISPLAYN := DISPLAYN+1;
70                   POINT(3) := DISPLAYN;
71                   POINT(4) := 1;
72                   POINT(5) := X;
73                   POINT(6) := Y;
74              'END STATEMENT';
75        <<
76              THE FOLLOWING DEFINES THE STATEMENT
77
78                        'CREATE LINE' LINE,P1,P2
79
80              WHICH HAS THE SAME EFFECT AS THE LIST OF STATEMENTS SHOWN
81        >>
82              'DEFINE STATEMENT' 'CREATE LINE' LINE,P1,P2;
83                   'ALLOCATE' LINE;
84                   LINE(1) := HEAD;
85                   HEAD := .PT. LINE;
86                   LINE(2) := (0 .AS. ('POINTER'));
87                   DISPLAYN := DISPLAYN+1;
88                   LINE(3) := DISPLAYN;
89                   LINE(4) := 2;
90                   LINE(5) := .PT. P1;
91                   LINE(6) := .PT. P2;
92              'END STATEMENT';
93        <<
94              THE FOLLOWING DEFINES THE STATEMENT
95
96                        'CONNECT' POINT 'TO' PICTURE
97
98              WHICH HAS THE SAME EFFECT AS THE LIST OF STATEMENT SHOWN
99        >>
100             'DECLARE SYNTACTIC CLASS' 'TO' 'SAME AS' , ;
101             'DEFINE STATEMENT' 'CONNECT' POINT 'TO' PICTURE;
102                  QQ1 := PICTURE;
103                  'IF' (QQ1 .AS. ('INTEGER')) = 0;
104                       PICTURE := .PT. POINT;
105                       POINT(2) := .PT. POINT;
106                  'ELSE';
107                       QQSV .EVAL. PICTURE;
108                       POINT(2) := QQSV(2);
109                       QQSV(2) := .PT. POINT;
110                  'END';
111             'END STATEMENT';
112       <<
113             THE FOLLOWING MACRO DEFINES THE .POINT. OPERATOR AS A PASS ONE MACRO.
114             IT CAUSES .POINT. A TO BE TREATED AS A(4) = 1
115       >>
116             'DECLARE SYNTACTIC CLASS' .POINT. 'SAME AS' .ABS.;
117             'DEFINE';
118             MACRO,.POINT.,T,B;
```

```
119             LOCAL,U;
120             TEMPORARY,U;
121             .TAG.,U,B,'LOCALLITERAL' 4;
122             LN=,T,U,'LOCALLITERAL' 1;
123             MEND,.POINT.;
124             END;
125     <<
126             THE FOLLOWING MACRO DEFINES .XOF. AS A PASS ONE OPERATOR.
127             IT CAUSES .XOF. A TO BE TREATED AS A(5)
128     >>
129             'DECLARE SYNTACTIC CLASS' .XOF. 'SAME AS' .ABS.;
130             'DEFINE';
131             MACRO,.XOF.,T,A;
132             .TAG.,T,A,'LOCALLITERAL' 5;
133             MEND,.XOF.;
134             END;
135     <<
136             THE FOLLOWING CAUSES .YOF. TO BE DEFINED AS A PASS ONE OPERATOR
137             .YOF. A HAS THE SAME EFFECT AS A(6)
138     >>
139             'DECLARE SYNTACTIC CLASS' .YOF. 'SAME AS' .ABS.;
140             'DEFINE';
141             MACRO,.YOF.,T,A;
142             .TAG.,T,A,'LOCALLITERAL' 6;
143             MEND,.YOF.;
144             END;
145     <<
146             THE FOLLOWING DEFINES .NEXT. A TO BE THE SAME AS A(2)
147     >>
148             'DECLARE SYNTACTIC CLASS' .NEXT. 'SAME AS' .ABS.;
149             'DEFINE';
150             MACRO,.NEXT.,T,A;
151             .TAG.,T,A,'LOCALLITERAL' 2;
152             MEND,.NEXT.;
153             END;
154     <<
155             THE FOLLOWING DEFINES .DISPN. A TO BE THE SAME AS A(3)
156     >>
157             'DECLARE SYNTACTIC CLASS' .DISPN. 'SAME AS' .ABS.;
158             'DEFINE';
159             MACRO,.DISPN.,T,A;
160             .TAG.,T,A,'LOCALLITERAL' 3;
161             MEND,.DISPN.;
162             END;
163             'DECLARE SYNTACTIC CLASS' .ENDA. 'SAME AS' .ABS.;
164             'DEFINE';
165             MACRO,.ENDA.,T,A;
166             .TAG.,T,A,'LOCALLITERAL' 5;
167             MEND,.ENDA.;
168             END;
169     <<
170             THE FOLLOWING DEFINES .ENDB. A TO BE THE SAME AS A(6)
171     >>
172             'DECLARE SYNTACTIC CLASS' .ENDB. 'SAME AS' .ABS.;
173             'DEFINE';
174             MACRO,.ENDB.,T,A;
175             .TAG.,T,A,'LOCALLITERAL' 6;
176             MEND,.ENDB.;
177             END;
178     <<
```

```
    179             THE FOLLOWING DEFINES .HEAD. A TO BE THE SAME AS A(1)
    180     >>
    181             'DECLARE SYNTACTIC CLASS' .HEAD. 'SAME AS' .ABS.;
    182             'DEFINE';
    183             MACRO,.HEAD.,T,A;
    184             .TAG.,T,A,'LOCALLITERAL' 1;
    185             MEND,.HEAD.;
    186             END;
    187     <<
    188             THE FOLLOWING DEFINES .ADROF. A TO BE THE SAME AS THE SEQUENCE OF
    189             STATEMENTS
    190                  QQSV .EVAL. HEAD
    191             B1:  'IF' .DISPN. QQSV = A, 'GO TO' B2
    192                  QQSV .EVAL. (.HEAD. QQSV)
    193                  'GO TO' B1
    194             B2:  'RETURN' .PT. QQSV
    195     >>
    196             'DECLARE SYNTACTIC CLASS' .ADROF. 'SAME AS' .ABS.;
    197             'DEFINE';
    198             MACRO,.ADROF.,T,A;
    199             LOCAL,B1,B2;
    200             LOCAL,T1,T2,T3,T4,T5;
    201             TEMPORARY,T1,T2,T3,T4,T5;
    202             FLAD,B1,B2;
    203             .EVAL.,T1,%QQSV,%HEAD;
    204             DES,B1;
    205             .DISPN.,T2,%QQSV;
    206             LN=,T3,T2,A;
    207             TNZ,B2,T3;
    208             .HEAD.,T4,%QQSV;
    209             .EVAL.,T5,%QQSV,T4;
    210             GUTO,B1;
    211             DES,B2;
    212             .PT.,T,%QQSV;
    213             MEND,.ADROF.;
    214             END;
    215     <<
    216                     END OF DEFINITIONAL PACKAGE
    217     >>
END OF FILE
```

Appendix C. Contents of File DEFFACILITY

```
$LIST DEFFACILITY
      1     <<
      2           THE FOLLOWING DEFINES THE NEW SIMPLE STATEMENT
      3
      4                 'DECLARE SYNTACTIC CLASS' A 'SAME AS' B
      5
      6           WHICH GIVES THE SYMBOL A EXACTLY THE SAME SYNTACTIC DEFINITION
      7           (CLASS,SYNTACTIC CLASS,LEFT PRECEDENCE,RIGHT PRECEDENCE) AS B.
      8           A WILL NOW BE TREATED EXACTLY AS B BY THE SYNTACTIC SCANNER.
      9     >>
     10           'DEFINE';                        <<ESCAPE INTO THE MACRO LANGUAGE>>
     11           SETUP,'DECLARE SYNTACTIC CLASS',14,3,4;      << SIMPLE KEYWORD>>
     12           MACRO,'DECLARE SYNTACTIC CLASS';        <<START THE MACRO DEF>>
     13           LOCAL,A;                         << A IS SAVED IN THIS LOCAL>>
     14           GTDSX;                           << THIS READS A>>
     15           SET,A,0,DSX;                     <<SAVE DSX OF A IN LOCAL SYMBOL>>
     16           GTDSX;                           <<NOW READ 'SAME AS'>>
     17           JMP,LOC+3,DSX = 'SAMEAS';        <<BE SURE IT REALLY IS 'SAMEAS'>>
     18           MNOTE,"****  ONLY 'SAME AS' IS ALLOWED";
     19           MEXIT;                           <<LEAVE HIM AT THE MERCY OF JSCAN>>
     20           GTDSX;                           <<READ B>>
     21           SET,IND.(A),1,DSX(1);            <<SET THE CLASS CODE OF A>>
     22           SET,IND.(A),2,DSX(2);            <<SET THE SYNTACTIC CLASS OF A>>
     23           SET,IND.(A),3,DSX(3);            <<SET THE LEFT PRECEDENCE OF A>>
     24           SET,IND.(A),4,DSX(4);            <<SET THE RIGHT PRECEDENCE OF A>>
     25           GTDSX;                           <<READ THE STATEMENT TERMINATOR>>
     26           MEND,'DECLARE SYNTACTIC CLASS';         <<ALL DONE>>
     27           END;                             <<BACK INTO MAD/I>>
     28     <<
     29           THE FOLLOWING DEFINES A SPECIAL PURPOSE DEFINITIONAL FACILITY
     30           WHICH ALLOWS THE DEFINITION OF A SIMPLE STATEMENT.  THE DEFINITIONAL
     31           STATEMENT IS OF THE FORM
     32
     33                'DEFINE STATEMENT' KEYWORD LIST OF VARIABLES
     34                     LIST OF STATEMENTS
     35                'END STATEMENT'
     36
     37           THE NEWLY DEFINED STATEMENT HAS THE FORM
     38
     39                KEYWORD  LIST OF EXPRESSIONS
     40
     41           EACH EXPRESSION WHICH WILL OCCUR IN AN INSTANCE OF THE DEFINED
     42           STATEMENT IS REPRESENTED BY A VARIABLE IN THE PROTOTYPE OF THE DEFINE
     43           STATEMENT.  IN THE CODE GENERATED FOR THE STATEMENT THE CODE FOR
     44           THE EXPRESSIONS WILL BE GENERATED FIRST, FOLLOWED BY THE CODE FOR THE
     45           MAD/I STATEMENTS SPECIFIED IN THE DEFINITION.  ALL OCCURENCES OF THE
     46           VARIABLES CORRESPONDING TO THE EXPRESSIONS ARE REPLACED BY THE
     47           RESULT OF THE CORRESPONDING EXPRESSION.
     48     >>
     49           'DECLARE SYNTACTIC CLASS' 'DEFINE STATEMENT' 'SAME AS' 'DEFINE';
     50           'DEFINE';                        <<ESCAPE INTO THE METALANGUAGE>>
     51           CREATE,DEFSTATLAB,DFSTLBC000,PERCLS(@VAL);   <<SETS UP CRS>>
     52           MACRO,'DEFINE STATEMENT';
     53           LOCAL,KEYWD,VLIST,SLIST,AVLIST,I,Q;
     54           GTDSX;                           << GET THE KEYWORD>>
     55           SETUP,DSX,14,3,4;                <<MAKE IT SIMPLE STATEMENT >>
     56           SET,KEYWD,0,DSX;                 <<KEYWD POINTS TO THE KEYWORD>>
     57           SET,KEYWD,1,INDCLS(@VAL);        <<AND IT IS INDIRECT>>
     58     A:    GTDSX;                           << GET A VARIABLE NAME>>
```

```
 59              JMP,B,DSX = LN; ;                  <<SEMICOLON MARKS THE END>>
 60              SETLST,VLIST,,DSX;                 << PUT THE VARIABLE INTO VLIST>>
 61              GTDSX;                             << GET THE COMMA OR SEMICOLON>>
 62              JMP,A,DSX ¬= LN; ;                 <<THERE IS ANOTHER VARIABLE>>
 63      B:      CRS,DEFSTATLAB,NOTIND.(DEFSTATLAB);     << A NEW LIST TO HOLD STM>>
 64              SET,SLIST,0,DEFSTATLAB;            <<SAVE THE LIST NAME>>
 65              SET,SLIST,1,INDCLS(@VAL);          << MAKE IT INDIRECT>>
 66              CRS,DEFSTATLAB,NOTIND.(DEFSTATLAB);     <<UNIQUE SYM FOR HIS VAR>>
 67              SETLST,NVLIST,,DEFSTATLAB;         <<BUILD A LIST OF THEM>>
 68              JMP,LOC-2,NVLIST(0) < VLIST(0);    <<WANT ONE FOR EACH VARIABLE>>
 69      C:      GTDSX;                  <<READ A STATEMENT DSX>>
 70              JMP,D,DSX = 'END STATEMENT';       <<CHECK FOR END OF DEFINITION>>
 71              SET,I,0,1;                         <<NOW CHECK FOR IT IN THE VARIABLES>>
 72              JMP,E,VLIST(I(0)) = DSX;           <<JUMP IF FOUND IT>>
 73              SET,I,0,I(0)+1;                    <<UP THE ANTE>>
 74              JMP,LOC-2,I(0) <= VLIST(0);        <<CONTINUE IF STILL MORE VARIABLES>>
 75              SETLST,SLIST,,DSX;                 << ADD HIS DSX TO THE STREAM>>
 76              JMP,C;                             << PROCESS THE NEXT DSX>>
 77      E:      SET,NOTIND.(DSX),0,NVLIST(I(0));   <<PERFORM THE SUBSTITUTION>>
 78              JMP,LOC-3;                         << AND NOW DO IT TO THIS>>
 79      D:      SETLST,SLIST,,'END';               <<PUT A 'END' ON THE END >>
 80              SETLST,SLIST,,LN;;                 << AND FINISH UP WITH A SEMICOLON >>
 81              MACRO,KEYWD;                       <<NOW DEFINE THE MACRO FOR THE KEYWD>>
 82              DESIST;
 83              SET,I,0,1;                  <<GENERATE AN EXPRESSION SCAN FOR EACH VAR>>
 84              JMP,LOC+10,I(0) > VLIST(0);        << STOP IF END OF LIST>>
 85              SET,NOTIND.(Q),0,NVLIST(I(0));     <<Q WILL BE THE VARIABLE NAME>>
 86              SET,NOTIND.(Q),1,INDCLS(@VAL);
 87              RESUME;
 88              JSCAN,,TAG,,LIST;          <<SCAN OFF AN EXPRESSION>>
 89              SET,Q,0,EXP.(1);                   <<MAKE THE VARIABLE THE RESULT>>
 90              SET,Q,1,INDCLS(@VAL);
 91              DESIST;
 92              SET,I,0,I(0)+1;                    <<UP TO THE NEXT VARIABLE>>
 93              JMP,LOC-9;                         << AROUND AND AROUND>>
 94              RESUME;
 95              SET,GTDSXLIST,0,SLIST;             << REDEFINE GTDSX FOR AWHILE >>
 96              BLOCK;                             << THESE LOOK LIKE SCOPE OF STM>>
 97              MEND,KEYWD;                        <<END THE GENERATED MACRO>>
 98              GTDSX;                             << GET OUR SEMICOLON>>
 99              MEND,'DEFINE STATEMENT';
100              END;                               <<BACK INTO MAD/I>>
101      <<
102              THE FOLLOWING REDEFINES THE PSEUDO OP FOR GTDSX.  THE NEW GTDSX ACTS
103              EXACTLY LIKE THE OLD DSX EXCEPT THAT IT WILL INSERT THE CONTENTS
104              OF THE LIST POINTED TO BY GTDSXLIST INTO THE INPUT STREAM.  THIS
105              ALLOWS A SEQUENCE OF DESCRIPTORS TO BE RETURNED TO JSCAN AS IF THEY
106              CAME FROM THE INPUT STREAM
107      >>
108              'DEFINE';
109              SET,PREVGTDSX,0,GTDSX(0);          << THIS IS NOW THE REAL GTDSX >>
110              SET,PREVGTDSX,1,GTDSX(1);
111              SET,GTDSXLIST,@SIZE,0;             << INITIALIZE GTDSX CHEAT LIST >>
112              SET,GTDSXLIST,0,0;                 << USE REAL GTDSX FOR THE TIME BEING >>
113              MACRO,GTDSX;                       << NOW REDEFINE GTDSX >>
114              JMP,LOC+3,GTDSXLIST(0) ¬= 0;       << JUMP IF INSERTIONS TO BE MADE >>
115              PREVGTDSX;                         << USE THE OLD-FASHION GTDSX >>
116              MEXIT;
117              SET,GTDSXLIST,@SIZE,GTDSXLIST(@SIZE)+1; << UP THE LIST INDEX >>
118              JMP,LOC+5,GTDSXLIST(@SIZE) <= (IND.(GTDSXLIST(0)))(0);
```

```
119                SET,GTDSXLIST,@SIZE,0;          << LIST PROCESSED SO RESET >>
120                SET,GTDSXLIST,0,0;
121                GTDSX;                          << NOW TRY READING AGAIN >>
122                MEXIT;
123                SET,NOTIND.(DSX),0,DSXOF.((IND.(GTDSXLIST(0)))(GTDSXLIST(@SIZE)));
124                SET,NOTIND.(DSX),1,INDCLS(0);       << SET UP DSX >>
125                MEND,GTDSX;
126                END;
127      <<
128                THE FOLLOWING MACRO CREATES A FLOATING ADDRESS CORRESPONDING TO
129                EACH PARAMETER
130      >>
131                'DEFINE';
132                MACRO,FLAD;
133                LOCAL,I;
134                SET,I,0,1;
135                JMP,LOC+2,PAR.(0) >= I(0);
136                MEXIT;
137                CRS,FLD,NOTIND.(FLD);
138                SET,FLD,1,NOTIND.(FLD)(@MOD);
139                SET,PAR.(I(0)),0,FLD;
140                SET,PAR.(I(0)),1,INDCLS(0);
141                SET,I,0,I(0)+1;
142                JMP,LOC-7;
143                MEND,FLAD;
144                END;
145      <<
146                THE FOLLOWING MACRO CREATES A TEMPORARY CORRESPONDING TO EACH PARAMETER
147      >>
148                'DEFINE';
149                MACRO,TEMPORARY;
150                LOCAL,I;
151                SET,I,0,1;
152                JMP,LOC+2,PAR.(0) >= I(0);
153                MEXIT;
154                CRS,TMP,NOTIND.(TMP);
155                SET,TMP,1,NOTIND.(TMP)(@MOD);
156                SET,PAR.(I(0)),0,TMP;
157                SET,PAR.(I(0)),1,INDCLS(0);
158                SET,I,0,I(0)+1;
159                JMP,LOC-7;
160                MEND,TEMPORARY;
161                END;
162      <<
163                THE FOLLOWING REDEFINES THE GETTEMP AND FREETEMP MACROS TO
164                GET AROUND THE PROBLEM OF THE REASSIGNMENT OF THE STORAGE
165                ALLOCATION OF A TEMPORARY.
166      >>
167                'DEFINE';
168                MACEXCTYPE,7;
169                MACDEFTYPE,2;
170                POPMACRO,GETTEMP,FREETEMP;
171                ATR,@TEMP1,EXTENDED;
172                ATR,@TEMP2,LOCAL,20,4;
173                SET,TEMPLST,@VAL,0;
174
175                MACRO,GETTEMP,S,MODE,LEN;
176                LOCAL,I,J;
177                JMP,LOC+4,LEN <= 16;
178      ERR:      MNOTE,"*****  GETTEMP CALLED FOR MORE THAN SIXTEEN BYTES.";
```

```
179                 DUMPDSX,S,MODE,LEN;
180                 MEXIT;
181                 CLEAR,S;
182                 SET,I,@VAL,5;
183                 SET,J,@VAL,0;
184       TEST:     JMP,DONE,I > TEMPLST;
185                 JMP,LOC+3,TEMPLST(I)(@TEMP2) ¬= 0;
186                 SET,J,@VAL,I;
187                 JMP,SEARCH;
188                 JMP,SEARCH,TEMPLST(I)(@TEMP2) ¬= DSXOF.(S);
189       GOOD:     SET,TEMPLST(I),@TEMP2,DSXOF.(S);
190                 SET,S,@XA,1;
191                 SET,S,@MODE,MODE(@MODE);
192                 SET,S,@LEN,LEN;
193                 SET,S,@VAL,TEMPLST(I);
194                 MEXIT;
195       SEARCH:   SET,I,@VAL,I+1;
196                 JMP,TEST;
197       DONE:     JMP,NO,J = 0;
198                 SET,I,@VAL,J;
199                 JMP,GOOD;
200       NO:       APND,TEMPLST,1,(;
201                 SET,TEMPLST,@VAL,I;
202                 SPACE,TEMPLST(I),16,8;
203                 JMP,GOOD;
204                 MEND,GETTEMP;
205
206                 MACRO,FREETEMP,S;
207                 LOCAL,I;
208                 RELSYMB,S;
209                 SET,I,@VAL,5;
210                 JMP,NO,I > TEMPLST;
211                 JMP,GOTIT,TEMPLST(I)(@TEMP2) = DSXOF.(S);
212                 SET,I,@VAL,I+1;
213                 JMP,LOC-3;
214       GOTIT:    SET,TEMPLST(I),@TEMP2,0;
215       NO:       SET,S,@VAL,0;
216                 SET,S,@XA,1;
217                 SET,S,@SIZE,0;
218                 SET,S,@CLS,NOTIND.(TMP)(@MOD);
219                 MEND,FREETEMP;
220
221                 MACDEFTYPE,1;
222                 MACEXCTYPE,1;
223                 END;
END OF FILE
```

Appendix D. Contents of File -DATA

```
$LIST -DATA
     1      DISPLAY
     2      POINT
     3      10 10
     4      POINT
     5      10 40
     6      POINT
     7      40 10
     8      POINT
     9      40 40
    10      DISPLAY
    11      LINE
    12      1 2
    13      LINE
    14      1 3
    15      LINE
    16      2 4
    17      LINE
    18      3 4
    19      DISPLAY
    20      MOVE
    21      1 15 20
    22      DISPLAY
    23      PICTURE
    24      1
    25      2
    26      3
    27      4
    28      0
    29      MOVE
    30      1 20 20
    31      DISPLAY
END OF FILE
```

Appendix E. Compilation of the MAD/I Program

```
$CREATE SKETCHOBJ
FILE ALREADY EXISTS
$EMPTY SKETCHOBJ
DONE.
$RUN *MAD1 SCARDS=SKETCH SPUNCH=SKETCHOBJ PAR=L
EXECUTION BEGINS
```

```
MAD/I COMPILER OPTION ASSIGNMENTS:

  SOURCE,DECK,LIST,SQRMGIN=(001,256),FREEFORM,CONTCHAR=+
  SOURCETAB=006,SIZE=(0003,0255),COMPILE
  NOMAP,NOXREF,ATR,OPLIST,USER,NOADDENCA

MAD/I COMPILER VERSION AN049-134322.

MAD/I COMPILER SOURCE PROGRAM LISTING ... ... ...


*0001          'PROCEDURE' SKETCH.;
*0002
*0003          'INCLUDE' "DISPLAYDEF"
*0004 <<
*0005                       DISPLAY DEFINITIONAL PACKAGE
*0006
*0007          THE FOLLOWING PARAMETER STATEMENT DEFINES THE COMPONENT STRUCTURE
*0008          FOR A POINT.  THE USER SIMPLY USES 'POINT' AS A MODE NAME IN
*0009          EITHER A 'DECLARE' STATEMENT OR AN @ CONSTRUCTION.  NOTE THAT
*0010          THE STATEMENT
*0011                    'POINT' (VARIABLE LIST)
*0012          WILL NOT WORK BECAUSE THIS IS SIMPLY A PARAMETRIC SUBSTITUTION.
*0013          THE STRUCTURE OF A POINT IS
*0014                    1    POINTER         POINTER TO NEXT LIST ITEM
*0015                    2    POINTER         POINTER TO NEXT ITEM IN SAME PICTURE
*0016                    3    INTEGER SHORT   DISPLAY ITEM NUMBER
*0017                    4    INTEGER SHORT   DISPLAY ITEM TYPE (1 FOR A POINT)
*0018                    5    INTEGER SHORT   X COORDINATE OF THE POINT
*0019                    6    INTEGER SHORT   Y COORDINATE OF THE POINT
*0020 >>
*0021          'PARAMETER' 'POINT' 'BASED' 'COMPONENT STRUCTURE'('POINTER',
*0022               'POINTER','INTEGER SHORT','INTEGER SHORT','INTEGER SHORT',
*0023               'INTEGER SHORT') 'ENDP'
*0024 <<
*0025          THE FOLLOWING PARAMETER STATEMENT DEFINES THE COMPONENT STRUCTURE
*0026          FOR A LINE.  THE USER SIMPLY USES 'LINE' AS A MODE NAME IN EITHER A
*0027          'DECLARE' STATEMENT OR AN @ CONSTRUCTION.  NOTE THAT THE STATEMENT
*0028                    'LINE' (VARIABLE LIST)
*0029          WILL NOT WORK BECAUSE THIS IS SIMPLY A PARAMETRIC SUBSTITUITION.
*0030          THE STRUCTURE OF A LINE IS
*0031                    1    POINTER         POINTER TO THE NEXT LIST ITEM
*0032                    2    POINTER         POINTER TO THE NEXT ITEM IN THE PICTURE
*0033                    3    INTEGER SHORT   DISPLAY ITEM NUMBER
*0034                    4    INTEGER SHORT   DISPLAY ITEM TYPE (2 FOR A LINE)
*0035                    5    POINTER         POINTER TO FIRST END-POINT
*0036                    6    POINTER         POINTER TO SECOND END-POINT
*0037 >>
*0038          'PARAMETER' 'LINE' 'BASED' 'COMPONENT STRUCTURE'('POINTER',
*0039               'POINTER','INTEGER SHORT','INTEGER SHORT','POINTER',
*0040               'POINTER') 'ENDP'
*0041 <<
*0042          THE FOLLOWING PARAMETER STATEMENT DEFINES THE MODE OF A PICTURE.
*0043          A PICTURE IS A POINTER TO ONE OF THE ITEMS IN THE PICTURE.  HENCE
*0044          IT IS SIMPLY PARAMETERIZED TO 'POINTER' MODE.
*0045 >>
*0046          'PARAMETER' 'PICTURE' 'POINTER' 'ENDP'
*0047 <<
*0048          THE FOLLOWING STATEMENTS DEFINE THE GLOBAL VARIABLES USED BY
*0049          THE DEFINITION PACKAGE.
```

```
*0050 >>
*0051          'DECLARE' DISPLAYN 'INTEGER SHORT';
*0052          'PRESET' DISPLAYN := 0;
*0053          'DECLARE' QQSV 'POINT';
*0054          'DECLARE' HEAD 'POINTER';
*0055          'PRESET' HEAD := 0;
*0056 <<
*0057          THE FOLLOWING BRINGS IN THE DEFINE FACILITY FROM THE FILE DEFFACILITY
*0058 >>
*0059          'INCLUDE' "DEFFACILITY"
*0060 <<
*0061          THE FOLLOWING DEFINES THE NEW SIMPLE STATEMENT
*0062
*0063                    'DECLARE SYNTACTIC CLASS' A 'SAME AS' B
*0064
*0065          WHICH GIVES THE SYMBOL A EXACTLY THE SAME SYNTACTIC DEFINITION
*0066          (CLASS,SYNTACTIC CLASS,LEFT PRECEDENCE,RIGHT PRECEDENCE) AS B.
*0067          A WILL NOW BE TREATED EXACTLY AS B BY THE SYNTACTIC SCANNER.
*0068 >>
*0069          'DEFINE';                          <<ESCAPE INTO THE MACRO LANGUAGE>>
*0070          SETUP,'DECLARE SYNTACTIC CLASS',14,3,4;      << SIMPLE KEYWORD>>
*0071          MACRO,'DECLARE SYNTACTIC CLASS';        <<START THE MACRO DEF>>
*0072          LOCAL,A;                           << A IS SAVED IN THIS LOCAL>>
*0073          GTDSX;                             << THIS READS A>>
*0074          SET,A,0,DSX;                       <<SAVE DSX OF A IN LOCAL SYMBOL>>
*0075          GTDSX;                             <<NOW READ 'SAME AS'>>
*0076          JMP,LOC+3,DSX = 'SAMEAS';          <<BE SURE IT REALLY IS 'SAMEAS'>>
*0077          MNOTE,"****  ONLY 'SAME AS' IS ALLOWED";
*0078          MEXIT;                             <<LEAVE HIM AT THE MERCY OF JSCAN>>
*0079          GTDSX;                             <<READ B>>
*0080          SET,IND.(A),1,DSX(1);              <<SET THE CLASS CODE OF A>>
*0081          SET,IND.(A),2,DSX(2);              <<SET THE SYNTACTIC CLASS OF A>>
*0082          SET,IND.(A),3,DSX(3);              <<SET THE LEFT PRECEDENCE OF A>>
*0083          SET,IND.(A),4,DSX(4);              <<SET THE RIGHT PRECEDENCE OF A>>
*0084          GTDSX;                             <<READ THE STATEMENT TERMINATOR>>
*0085          MEND,'DECLARE SYNTACTIC CLASS';         <<ALL DONE>>
*0086          END;                               <<BACK INTO MAD/I>>
*0087 <<
*0088          THE FOLLOWING DEFINES A SPECIAL PURPOSE DEFINITIONAL FACILITY
*0089          WHICH ALLOWS THE DEFINITION OF A SIMPLE STATEMENT.  THE DEFINITIONAL
*0090          STATEMENT IS OF THE FORM
*0091
*0092               'DEFINE STATEMENT' KEYWORD LIST OF VARIABLES
*0093                    LIST OF STATEMENTS
*0094               'END STATEMENT'
*0095
*0096          THE NEWLY DEFINED STATEMENT HAS THE FORM
*0097
*0098               KEYWORD  LIST OF EXPRESSIONS
*0099
*0100          EACH EXPRESSION WHICH WILL OCCUR IN AN INSTANCE OF THE DEFINED
*0101          STATEMENT IS REPRESENTED BY A VARIABLE IN THE PROTOTYPE OF THE DEFINE
*0102          STATEMENT.  IN THE CODE GENERATED FOR THE STATEMENT THE CODE FOR
*0103          THE EXPRESSIONS WILL BE GENERATED FIRST, FOLLOWED BY THE CODE FOR THE
*0104          MAD/I STATEMENTS SPECIFIED IN THE DEFINITION.  ALL OCCURENCES OF THE
*0105          VARIABLES CORRESPONDING TO THE EXPRESSIONS ARE REPLACED BY THE
*0106          RESULT OF THE CORRESPONDING EXPRESSION.
*0107 >>
*0108          'DECLARE SYNTACTIC CLASS' 'DEFINE STATEMENT' 'SAME AS' 'DEFINE';
*0109          'DEFINE';                          <<ESCAPE INTO THE METALANGUAGE>>
```

```
*0110          CREATE,DEFSTATLAB,DFSTLB0000,PERCLS(@VAL);   <<SETS UP CRS>>
*0111          MACRO,'DEFINE STATEMENT';
*0112          LOCAL,KEYWD,VLIST,SLIST,NVLIST,I,Q;
*0113          GTDSX;                          << GET THE KEYWORD>>
*0114          SETUP,DSX,14,3,4;               <<MAKE IT SIMPLE STATEMENT >>
*0115          SET,KEYWD,0,DSX;                <<KEYWD POINTS TO THE KEYWORD>>
*0116          SET,KEYWD,1,INDCLS(@VAL);       <<AND IT IS INDIRECT>>
*0117 A:       GTDSX;                          << GET A VARIABLE NAME>>
*0118          JMP,B,DSX = LN; ;               <<SEMICOLON MARKS THE END>>
*0119          SETLST,VLIST,,DSX;              << PUT THE VARIABLE INTO VLIST>>
*0120          GTDSX;                          << GET THE COMMA OR SEMICOLON>>
*0121          JMP,A,DSX ¬= LN; ;              <<THERE IS ANOTHER VARIABLE>>
*0122 B:       CRS,DEFSTATLAB,NOTIND.(DEFSTATLAB);     << A NEW LIST TO HOLD STM>>
*0123          SET,SLIST,0,DEFSTATLAB;         <<SAVE THE LIST NAME>>
*0124          SET,SLIST,1,INDCLS(@VAL);       << MAKE IT INDIRECT>>
*0125          CRS,DEFSTATLAB,NOTIND.(DEFSTATLAB);     <<UNIQUE SYM FOR HIS VAR>>
*0126          SETLST,NVLIST,,DEFSTATLAB;      <<BUILD A LIST OF THEM>>
*0127          JMP,LOC-2,NVLIST(0) < VLIST(0);     <<WANT ONE FOR EACH VARIABLE>>
*0128 C:       GTDSX;                  <<READ A STATEMENT DSX>>
*0129          JMP,D,DSX = 'END STATEMENT';  <<CHECK FOR END OF DEFINITION>>
*0130          SET,I,0,1;                      <<NOW CHECK FOR IT IN THE VARIABLES>>
*0131          JMP,E,VLIST(I(0)) = DSX;        <<JUMP IF FOUND IT>>
*0132          SET,I,0,I(0)+1;                 <<UP THE ANTE>>
*0133          JMP,LOC-2,I(0) <= VLIST(0);     <<CONTINUE IF STILL MORE VARIABLES>>
*0134          SETLST,SLIST,,DSX;              << ADD HIS DSX TO THE STREAM>>
*0135          JMP,C;                          << PROCESS THE NEXT DSX>>
*0136 E:       SET,NOTIND.(DSX),0,NVLIST(I(0));    <<PERFORM THE SUBSTITUTION>>
*0137          JMP,LOC-3;                      << AND NOW DO IT TO THIS>>
*0138 D:       SETLST,SLIST,,'END';            <<PUT A 'END' ON THE END >>
*0139          SETLST,SLIST,,LN;;              << AND FINISH UP WITH A SEMICOLON >>
*0140          MACRO,KEYWD;                    <<NOW DEFINE THE MACRO FOR THE KEYWD>>
*0141          DESIST;
*0142          SET,I,0,1;                <<GENERATE AN EXPRESSION SCAN FOR EACH VAR>>
*0143          JMP,LOC+10,I(0) > VLIST(0);   << STOP IF END OF LIST>>
*0144          SET,NOTIND.(Q),0,NVLIST(I(0));      <<Q WILL BE THE VARIABLE NAME>>
*0145          SET,NOTIND.(Q),1,INDCLS(@VAL);
*0146          RESUME;
*0147          JSCAN,.TAG.,LIST;         <<SCAN OFF AN EXPRESSION>>
*0148          SET,Q,0,EXP.(1);                <<MAKE THE VARIABLE THE RESULT>>
*0149          SET,Q,1,INDCLS(@VAL);
*0150          DESIST;
*0151          SET,I,0,I(C)+1;                 <<UP TO THE NEXT VARIABLE>>
*0152          JMP,LOC-9;                      << AROUND AND AROUND>>
*0153          RESUME;
*0154          SET,GTDSXLIST,0,SLIST;          << REDEFINE GTDSX FOR AWHILE >>
*0155          BLOCK;                          << THESE LOOK LIKE SCOPE OF STM>>
*0156          MEND,KEYWD;                     <<END THE GENERATED MACRO>>
*0157          GTDSX;                          << GET OUR SEMICOLON>>
*0158          MEND,'DEFINE STATEMENT';
*0159          END;                            <<BACK INTO MAD/I>>
*0160 <<
*0161          THE FOLLOWING REDEFINES THE PSEUDO OP FOR GTDSX.  THE NEW GTDSX ACTS
*0162          EXACTLY LIKE THE OLD DSX EXCEPT THAT IT WILL INSERT THE CONTENTS
*0163          OF THE LIST POINTED TO BY GTDSXLIST INTO THE INPUT STREAM.  THIS
*0164          ALLOWS A SEQUENCE OF DESCRIPTORS TO BE RETURNED TO JSCAN AS IF THEY
*0165          CAME FROM THE INPUT STREAM
*0166 >>
*0167          'DEFINE';
*0168          SET,PREVGTDSX,0,GTDSX(0);       << THIS IS NOW THE REAL GTDSX >>
*0169          SET,PREVGTDSX,1,GTDSX(1);
```

```
*0170           SET,GTDSXLIST,@SIZE,0;          << INITIALIZE GTDSX CHEAT LIST >>
*0171           SET,GTDSXLIST,0,0;              << USE REAL GTDSX FOR THE TIME BEING >>
*0172           MACRO,GTDSX;                    << NOW REDEFINE GTDSX >>
*0173           JMP,LOC+3,GTDSXLIST(0) ¬= 0;    << JUMP IF INSERTIONS TO BE MADE >>
*0174           PREVGTDSX;                      << USE THE OLD-FASHION GTDSX >>
*0175           MEXIT;
*0176           SET,GTDSXLIST,@SIZE,GTDSXLIST(@SIZE)+1; << UP THE LIST INDEX >>
*0177           JMP,LOC+5,GTDSXLIST(@SIZE) <= (IND.(GTDSXLIST(0)))(0);
*0178           SET,GTDSXLIST,@SIZE,0;          << LIST PROCESSED SO RESET >>
*0179           SET,GTDSXLIST,0,0;
*0180           GTDSX;                          << NOW TRY READING AGAIN >>
*0181           MEXIT;
*0182           SET,NOTIND.(DSX),0,DSXOF.((IND.(GTDSXLIST(0)))(GTDSXLIST(@SIZE)));
*0183           SET,NOTIND.(DSX),1,INDCLS(0);       << SET UP DSX >>
*0184           MEND,GTDSX;
*0185           END;
*0186 <<
*0187           THE FOLLOWING MACRO CREATES A FLOATING ADDRESS CORRESPONDING TO
*0188           EACH PARAMETER
*0189 >>
*0190           'DEFINE';
*0191           MACRO,FLAD;
*0192           LOCAL,I;
*0193           SET,I,0,1;
*0194           JMP,LOC+2,PAR.(0) >= I(0);
*0195           MEXIT;
*0196           CRS,FLD,NOTIND.(FLD);
*0197           SET,FLD,1,NOTIND.(FLD)(@MOD);
*0198           SET,PAR.(I(0)),0,FLD;
*0199           SET,PAR.(I(0)),1,INDCLSIO);
*0200           SET,I,0,I(0)+1;
*0201           JMP,LOC-7;
*0202           MEND,FLAD;
*0203           END;
*0204 <<
*0205           THE FOLLOWING MACRO CREATES A TEMPORARY CORRESPONDING TO EACH PARAMETER
*0206 >>
*0207           'DEFINE';
*0208           MACRO,TEMPORARY;
*0209           LOCAL,I;
*0210           SET,I,0,1;
*0211           JMP,LOC+2,PAR.(0) >= I(0);
*0212           MEXIT;
*0213           CRS,TMP,NOTIND.(TMP);
*0214           SET,TMP,1,NOTIND.(TMP)(@MOD);
*0215           SET,PAR.(I(C)),0,TMP;
*0216           SET,PAR.(I(0)),1,INDCLS(0);
*0217           SET,I,0,I(0)+1;
*0218           JMP,LOC-7;
*0219           MEND,TEMPORARY;
*0220           END;
*0221 <<
*0222           THE FOLLOWING REDEFINES THE GETTEMP AND FREETEMP MACROS TO
*0223           GET AROUND THE PROBLEM OF THE REASSIGNMENT OF THE STORAGE
*0224           ALLOCATION OF A TEMPORARY.
*0225 >>
*0226           'DEFINE';
*0227           MACEXCTYPE,7;
*0228           MACDEFTYPE,2;
*0229           POPMACRO,GETTEMP,FREETEMP;
```

```
*0230           ATR,@TEMP1,EXTENDED;
*0231           ATR,@TEMP2,LOCAL,20,4;
*0232           SET,TEMPLST,@VAL,0;
*0233
*0234           MACRO,GETTEMP,S,MODE,LEN;
*0235           LOCAL,I,J;
*0236           JMP,LOC+4,LEN <= 16;
*0237 ERR:      MNOTE,"****  GETTEMP CALLED FOR MORE THAN SIXTEEN BYTES.";
*0238           DUMPDSX,S,MODE,LEN;
*0239           MEXIT;
*0240           CLEAR,S;
*0241           SET,I,@VAL,5;
*0242           SET,J,@VAL,0;
*0243 TEST:     JMP,DONE,I > TEMPLST;
*0244           JMP,LOC+3,TEMPLST(I)(@TEMP2) ¬= 0;
*0245           SET,J,@VAL,I;
*0246           JMP,SEARCH;
*0247           JMP,SEARCH,TEMPLST(I)(@TEMP2) ¬= DSXOF.(S);
*0248 GOOD:     SET,TEMPLST(I),@TEMP2,DSXOF.(S);
*0249           SET,S,@XA,1;
*0250           SET,S,@MODE,MODE(@MODE);
*0251           SET,S,@LEN,LEN;
*0252           SET,S,@VAL,TEMPLST(I);
*0253           MEXIT;
*0254 SEARCH:   SET,I,@VAL,I+1;
*0255           JMP,TEST;
*0256 DONE:     JMP,NO,J = 0;
*0257           SET,I,@VAL,J;
*0258           JMP,GOOD;
*0259 NO:       APND,TEMPLST,1,I;
*0260           SET,TEMPLST,@VAL,I;
*0261           SPACE,TEMPLST(I),16,8;
*0262           JMP,GOOD;
*0263           MEND,GETTEMP;
*0264
*0265           MACRO,FREETEMP,S;
*0266           LOCAL,I;
*0267           RELSYMB,S;
*0268           SET,I,@VAL,5;
*0269           JMP,NO,I > TEMPLST;
*0270           JMP,GOTIT,TEMPLST(I)(@TEMP2) = DSXOF.(S);
*0271           SET,I,@VAL,I+1;
*0272           JMP,LOC-3;
*0273 GOTIT:    SET,TEMPLST(I),@TEMP2,0;
*0274 NO:       SET,S,@VAL,0;
*0275           SET,S,@XA,1;
*0276           SET,S,@SIZE,0;
*0277           SET,S,@CLS,NOTIND.(TMP)(@MOD);
*0278           MEND,FREETEMP;
*0279
*0280           MACDEFTYPE,1;
*0281           MACEXCTYPE,1;
*0282           END;
*0283 <<
*0284           THE FOLLOWING DEFINES THE STATEMENT
*0285
*0286                'CREATE POINT' POINT,X,Y
*0287
*0288           WHICH HAS THE EFFECT OF THE LIST OF STATEMENTS SHOWN
*0289 >>
```

```
*0290          'DEFINE STATEMENT' 'CREATE PCINT' POINT,X,Y;
*0291               'ALLOCATE' POINT;
*0292               POINT(1) := HEAD;
*0293               HEAD := .PT. POINT;
*0294               POINT(2) := (0 .AS. ('PCINTER'));
*0295               DISPLAYN := DISPLAYN+1;
*0296               POINT(3) := DISPLAYN;
*0297               POINT(4) := 1;
*0298               POINT(5) := X;
*0299               POINT(6) := Y;
*0300          'END STATEMENT';
*0301 <<
*0302          THE FOLLOWING DEFINES THE STATEMENT
*0303
*0304                    'CREATE LINE' LINE,P1,P2
*0305
*0306          WHICH HAS THE SAME EFFECT AS THE LIST OF STATEMENTS SHOWN
*0307 >>
*0308          'DEFINE STATEMENT' 'CREATE LINE' LINE,P1,P2;
*0309               'ALLOCATE' LINE;
*0310               LINE(1) := HEAD;
*0311               HEAD := .PT. LINE;
*0312               LINE(2) := (0 .AS. ('PCINTER'));
*0313               DISPLAYN := DISPLAYN+1;
*0314               LINE(3) := DISPLAYN;
*0315               LINE(4) := 2;
*0316               LINE(5) := .PT. P1;
*0317               LINE(6) := .PT. P2;
*0318          'END STATEMENT';
*0319 <<
*0320          THE FOLLOWING DEFINES THE STATEMENT
*0321
*0322                    'CONNECT' POINT 'TC' PICTURE
*0323
*0324          WHICH HAS THE SAME EFFECT AS THE LIST OF STATEMENT SHOWN
*0325 >>
*0326          'DECLARE SYNTACTIC CLASS' 'TO' 'SAME AS' , ;
*0327          'DEFINE STATEMENT' 'CONNECT' POINT 'TO' PICTURE;
*0328               QQ1 := PICTURE;
*0329               'IF' (QQ1 .AS. ('INTEGER')) = 0;
*0330                    PICTURE := .PT. POINT;
*0331                    POINT(2) := .PT. PCINT;
*0332               'ELSE';
*0333                    QQSV .EVAL. PICTURE;
*0334                    POINT(2) := QQSV(2);
*0335                    QQSV(2) := .PT. POINT;
*0336               'END';
*0337          'END STATEMENT';
*0338 <<
*0339          THE FOLLOWING MACRO DEFINES THE .POINT. OPERATOR AS A PASS ONE MACRO.
*0340          IT CAUSES .POINT. A TO BE TREATED AS A(4) = 1
*0341 >>
*0342          'DECLARE SYNTACTIC CLASS' .POINT. 'SAME AS' .ABS.;
*0343          'DEFINE';
*0344          MACRO,.POINT.,T,B;
*0345          LOCAL,U;
*0346          TEMPORARY,U;
*0347          .TAG.,U,B,'LOCALLITERAL' 4;
*0348          LN=,T,U,'LOCALLITERAL' 1;
*0349          MEND,.POINT.;
```

```
*0350           END;
*0351 <<
*0352           THE FOLLOWING MACRO DEFINES .XOF. AS A PASS ONE OPERATOR.
*0353           IT CAUSES .XOF. A TO BE TREATED AS A(5)
*0354 >>
*0355           'DECLARE SYNTACTIC CLASS' .XOF. 'SAME AS' .ABS.;
*0356           'DEFINE';
*0357           MACRO,.XOF.,T,A;
*0358           .TAG.,T,A,'LOCALLITERAL' 5;
*0359           MEND,.XOF.;
*0360           END;
*0361 <<
*0362           THE FOLLOWING CAUSES .YOF. TO BE DEFINED AS A PASS ONE OPERATOR
*0363           .YOF. A HAS THE SAME EFFECT AS A(6)
*0364 >>
*0365           'DECLARE SYNTACTIC CLASS' .YOF. 'SAME AS' .ABS.;
*0366           'DEFINE';
*0367           MACRO,.YOF.,T,A;
*0368           .TAG.,T,A,'LOCALLITERAL' 6;
*0369           MEND,.YOF.;
*0370           END;
*0371 <<
*0372           THE FOLLOWING DEFINES .NEXT. A TO BE THE SAME AS A(2)
*0373 >>
*0374           'DECLARE SYNTACTIC CLASS' .NEXT. 'SAME AS' .ABS.;
*0375           'DEFINE';
*0376           MACRO,.NEXT.,T,A;
*0377           .TAG.,T,A,'LOCALLITERAL' 2;
*0378           MEND,.NEXT.;
*0379           END;
*0380 <<
*0381           THE FOLLOWING DEFINES .DISPN. A TO BE THE SAME AS A(3)
*0382 >>
*0383           'DECLARE SYNTACTIC CLASS' .DISPN. 'SAME AS' .ABS.;
*0384           'DEFINE';
*0385           MACRO,.DISPN.,T,A;
*0386           .TAG.,T,A,'LOCALLITERAL' 3;
*0387           MEND,.DISPN.;
*0388           END;
*0389           'DECLARE SYNTACTIC CLASS' .ENDA. 'SAME AS' .ABS.;
*0390           'DEFINE';
*0391           MACRO,.ENDA.,T,A;
*0392           .TAG.,T,A,'LOCALLITERAL' 5;
*0393           MEND,.ENDA.;
*0394           END;
*0395 <<
*0396           THE FOLLOWING DEFINES .ENDB. A TO BE THE SAME AS A(6)
*0397 >>
*0398           'DECLARE SYNTACTIC CLASS' .ENDB. 'SAME AS' .ABS.;
*0399           'DEFINE';
*0400           MACRO,.ENDB.,T,A;
*0401           .TAG.,T,A,'LOCALLITERAL' 6;
*0402           MEND,.ENDB.;
*0403           END;
*0404 <<
*0405           THE FOLLOWING DEFINES .HEAD. A TO BE THE SAME AS A(1)
*0406 >>
*0407           'DECLARE SYNTACTIC CLASS' .HEAD. 'SAME AS' .ABS.;
*0408           'DEFINE';
*0409           MACRO,.HEAD.,T,A;
```

```
*0410           .TAG.,T,A,'LOCALLITERAL' 1;
*0411           MEND,.HEAD.;
*0412           END;
*0413 <<
*0414           THE FOLLOWING DEFINES .ADROF. A TO BE THE SAME AS THE SEQUENCE OF
*0415           STATEMENTS
*0416                QQSV .EVAL. HEAD
*0417           B1:  'IF' .DISPN. QQSV = A, 'GO TO' B2
*0418                QQSV .EVAL. (.HEAD. QQSV)
*0419                'GO TO' B1
*0420           B2:  'RETURN' .PT. QQSV
*0421 >>
*0422           'DECLARE SYNTACTIC CLASS' .ADROF. 'SAME AS' .ABS.;
*0423           'DEFINE';
*0424           MACRO,.ADROF.,T,A;
*0425           LOCAL,B1,B2;
*0426           LOCAL,T1,T2,T3,T4,T5;
*0427           TEMPORARY,T1,T2,T3,T4,T5;
*0428           FLAD,B1,B2;
*0429           .EVAL.,T1,%QQSV,%HEAD;
*0430           DES,B1;
*0431           .DISPN.,T2,%QQSV;
*0432           LN=,T3,T2,A;
*0433           TNZ,B2,T3;
*0434           .HEAD.,T4,%QQSV;
*0435           .EVAL.,T5,%QQSV,T4;
*0436           GOTO,B1;
*0437           DES,B2;
*0438           .PT.,T,%QQSV;
*0439           MEND,.ADROF.;
*0440           END;
*0441 <<
*0442                   END OF DEFINITIONAL PACKAGE
*0443 >>
*0444
*0445           'DECLARE' 'NORMAL MODE' 'INTEGER';
*0446           'DECLARE' COMMAND 'CHARACTER'(4);
*0447           'DECLARE' DISPLAY 'FIXED ARRAY'(50,50) 'CHARACTER'(1);
*0448           'DECLARE' (POINT,P1,P2,P3) 'POINT';
*0449           'DECLARE' LINE 'LINE';
*0450           'DECLARE' PICTURE 'FIXED ARRAY'(100) 'PICTURE';
*0451           'DECLARE' QQ1 'POINTER';
*0452           'DECLARE' QQ2 'POINTER';
*0453           'DECLARE' (M,M1,M2) 'FLOATING';
*0454
*0455           'PRESET' PICTUREN := 0;
*0456
*0457
*0458 SKETCH:   'WRITE' , "'0ENTER A COMMAND PLEASE.'*";
*0459           'READ' , "C4.4*" , COMMAND;
*0460
*0461           'IF' COMMAND = "POIN";
*0462                'WRITE' , "' ENTER X AND Y COORDINATES:'*";
*0463                'READ' , "2I*", X,Y;
*0464                'IF' 1 <= X & 50 >= X & 1 <= Y & 50 >= Y;
*0465                     'CREATE POINT' POINT,X,Y;
*0466                     'WRITE' , "' ASSIGNED DISPLAY NUMBER',HI4*", .DISPN. POINT;
*0467                'ELSE';
*0468                     'WRITE' , "' POINT IS OUTSIDE RASTER RANGE.'*";
*0469                'END';
```

```
*0470
*0471           'OR IF' COMMAND = "LINE";
*0472                'WRITE' , "' ENTER DISPLAY NUMBERS FOR END-POINTS:'*";
*0473                'READ' , "2I*", X,Y;
*0474                P1 .EVAL. .ADROF. X; P2 .EVAL. .ADROF. Y;
*0475                'IF' .POINT. P1 & .POINT. P2;
*0476                     'CREATE LINE' LINE,P1,P2;
*0477                'ELSE';
*0478 NOTPOINT:           'WRITE' , "' THOSE ARE NOT POINTS.'*";
*0479                'END';
*0480
*0481           'OR IF' COMMAND = "PICT";
*0482                'WRITE' , "' ENTER DISPLAY NUMBERS FOR ALL POINTS.'*";
*0483                PICTUREN := PICTUREN+1;
*0484                'IF' PICTUREN > 100;
*0485                     'WRITE' , "' TOO MANY PICTURES.'*";
*0486                'ELSE';
*0487                     PICTURE(PICTUREN) := 0 .AS. ('POINTER');
*0488 PICTA:               'READ' , "I*", X;
*0489                     'IF' X¬= 0;
*0490                          P1 .EVAL. .ADROF. X;
*0491                          'IF' ¬.POINT. P1, 'GO TO' NOTPOINT;
*0492                          QQ2 := PICTURE(PICTUREN);
*0493                          'CONNECT' P1 'TO' QQ2;
*0494                          PICTURE(PICTUREN) := QQ2;
*0495                          'GO TO' PICTA;
*0496                     'END'
*0497                'END';
*0498
*0499           'OR IF' COMMAND = "MOVE";
*0500                'WRITE' , "' ENTER DISPLAY NUMBER OF POINT AND NEW X,Y'*";
*0501                'READ' , "3I*", DIS,X,Y;
*0502                P1 .EVAL. .ADROF. DIS;
*0503                'IF' ¬.POINT. P1, 'GOTO' NOTPOINT;
*0504                DX := X-.XOF. P1; DY := Y-.YOF. P1;
*0505                (.XOF. P1) := .XOF. P1+DX; (.YOF. P1) := .YOF. P1+DY;
*0506                QQ1 := P1(2);
*0507                'IF' QQ1 .AS. ('INTEGER') ¬= 0;
*0508                     P2 .EVAL. .NEXT. P1;
*0509 MOVEA:              'IF' .DISPN. P1 ¬= .DISPN. P2;
*0510                          (.XOF. P2) := .XOF. P2+DX; (.YOF. P2) := .YOF. P2
*0511                                                              +DY;
*0512                          P2 .EVAL. .NEXT. P2;
*0513                          'GO TO' MOVEA;
*0514                     'END'
*0515                'END';
*0516
*0517           'OR IF' COMMAND = "DISP";
*0518                'IF' HEAD .AS. ('INTEGER') = 0;
*0519                     'WRITE' , "' NOTHING TO DISPLAY.'*";
*0520                     'GO TO' SKETCH;
*0521                'END';
*0522                'FOR' I := 1,1,I>50, 'FOR' J := 1,1,J>50, DISPLAY(I,J) := " ";
*0523                P1 .EVAL. HEAD;
*0524 DISPA:          ;
*0525                'IF' .POINT. P1;
*0526                     Q1 := .XOF. P1; Q2 := .YOF. P1; DISPLAY(Q2,Q1) := "*";
*0527                'ELSE';
*0528                     LINE .EVAL. (.PT. P1);
*0529                     QQ1 := .ENDA. LINE; P2 .EVAL. QQ1;
```

```
*0530                    QQ1 := .ENDB. LINE; P3 .EVAL. QQ1;
*0531                    X1 := MIN.(.XOF. P2,.XOF. P3);
*0532                    X2 := MAX.(.XOF. P2,.XOF. P3);
*0533                    'IF' X1 = X2;
*0534                         Y1 := MIN.(.YOF. P2,.YOF. P3);
*0535                         Y2 := MAX.(.YOF. P2,.YOF. P3);
*0536                         'FOR' Y := Y1,1, Y > Y2, DISPLAY(Y,X1) := "*";
*0537                    'ELSE';
*0538                         M1 := .YOF. P3 - .YOF. P2;
*0539                         M2 := .XOF. P3 - .XOF. P2;
*0540                         M := M1/M2;
*0541                         'FOR' X := X1,1,X > X2;
*0542                              Q2 := M*(X - .XOF. P2) + .YOF. P2;
*0543                              DISPLAY(Q2,X) := "*";
*0544                         'END';
*0545                    'END';
*0546               'END';
*0547               QQ1 := .HEAD. P1;
*0548               'IF' QQ1 .AS. ('INTEGER') -= 0;
*0549                    P1 .EVAL. .HEAD. P1;
*0550                    'GO TO' DISPA;
*0551               'END';
*0552               'WRITE' , "'1   .',10('    .')*";
*0553               'FOR' I := 50,-1, I < 1,
*0554                    'WRITE' , "I3,52C1.1*", I," ","."
*0555                                          DISPLAY(I,1)...DISPLAY(I,50);
*0556               'WRITE' , "'    .',10('    .')*";
*0557
*0558          'ELSE';
*0559               'WRITE' , "' ILLEGAL COMMAND'*";
*0560          'END';
*0561
*0562          'GO TO' SKETCH;
*0563
*0564          'PROCEDURE' MIN.(X,Y);
*0565          'INTEGER SHORT' (X,Y);
*0566 MIN:     'IF' X <= Y, 'RETURN' X;
*0567          'RETURN' Y;
*0568          'END';
*0569
*0570          'PROCEDURE' MAX.(A,B);
*0571          'INTEGER SHORT' (A,B);
*0572 MAX:     'IF' A >= B, 'RETURN' A;
*0573          'RETURN' B;
*0574          'END';
*0575
*0576          'END'
```

```
TORAGE ALLOCATION


1 000000                          ##SKETCH CSECT
1 000470 00000001               +         CONST 1
1 000474 00000001               +         CONST 1
1 000478 00000064               +         CONST 100
1 000480 00000002               +         CONST 2
1 000484 00000001               +         CONST 1
1 000488 00000032               +         CONST 50
1 00048C 00000001               +         CONST 1
1 000490 00000032               +         CONST 50
1 000080 00000000               +         CONST 0
1 000084 00000000               +         CONST 0
1 000084 00000000               +         CONST 0
1 00029C 7D40C9D3D3C5C7C1       +         CONST "' ILLEGAL COMMAND'*"
1 0002AF 7D4040404047D6B        +         CONST "'    .',10('    .')*"
1 0002C3 4B                     +         CONST ".*"
1 0002C4 C9F36BF5F2C3F14B       +         CONST "I3,52C1.1*"
1 0002CE 7DF14040404B7D6B       +         CONST "'1   .',10('    .')*"
1 0002E2 5C                     +         CONST "*"
1 0002E3 40                     +         CONST " "
1 0002E4 7D40D5D6E3C8C9D5       +         CONST "' NOTHING TO DISPLAY.'*"
1 0002FB C4C9E2D7               +         CONST "DISP"
1 0002FF F3C95C                 +         CONST "3I*"
1 000302 7D40C5D5E3C5D94C       +         CONST "' ENTER DISPLAY NUMBER OF POINT AND NEW X,Y'*"
1 00032F D4D6E5C5               +         CONST "MOVE"
1 000333 C95C                   +         CONST "I*"
1 000335 7D40E3D6D640D4C1       +         CONST "' TOO MANY PICTURES.'*"
1 00034C 00000064               +         CONST 100
1 000350 7D40C5D5E3C5D94C       +         CONST "' ENTER DISPLAY NUMBERS FOR ALL POINTS.'*"
1 000379 D7C9C3E3               +         CONST "PICT"
1 00037D 7D40E3C8D6E2C54C       +         CONST "' THOSE ARE NOT POINTS.'*"
1 000396 7D40C5D5E3C5D94C       +         CONST "' ENTER DISPLAY NUMBERS FOR END-POINTS:'*"
1 0003BF D3C9D5C5               +         CONST "LINE"
1 0003C3 7D40D7D6C9D5E34C       +         CONST "' POINT IS OUTSIDE RASTER RANGE.'*"
1 0003E5 7D40C1E2E2C9C7D5       +         CONST "' ASSIGNED DISPLAY NUMBER',HI4*"
1 000404 00000032               +         CONST 50
1 000408 F2C95C                 +         CONST "2I*"
1 00040B 7D40C5D5E3C5D94C       +         CONST "' ENTER X AND Y COORDINATES:'*"
1 000429 D7D6C9D5               +         CONST "POIN"
1 00042D C3F448F45C             +         CONST "C4.4*"
1 000432 7DF0C5D5E3C5D94C       +         CONST "'CENTER A COMMAND PLEASE.'*"
1 000450 00000006               +         CONST 6
1 000454 00000005               +         CONST 5
1 000458 00000004               +         CONST 4
1 00045C 00000003               +         CONST 3
1 000460 00000000               +         CONST 0
1 000464 00000002               +         CONST 2
1 000468 00000001               +         CONST 1
```

STORAGE MAP

```
00 03 0028 00000DC0 Y
00 03 002C 00000D00 X
00 03 0030 00000DC0 B
00 03 0034 00000000 A
00 07 0010 000000C0 P3
00 07 0014 00000000 P2
00 07 0018 00000000 P1
00 07 001C 00000000 LINE
00 07 0020 00000000 POINT
00 07 0024 00000000 QQSV
01 01 0000 00000000 Y2
01 01 0000 00000004 Y1
01 01 0000 00000008 MAX
01 01 0000 00000010 X2
01 01 0000 00000014 MIN
01 01 0000 0000001C X1
01 01 0000 00000020 Q2
01 01 0000 00000024 Q1
01 01 0000 00000028 DISPA
01 01 0000 00000030 J
01 01 0000 00000034 I
01 01 0000 00000038 MOVEA
01 01 0000 00000040 DY
01 01 0000 00000044 DX
01 01 0000 00000048 DIS
01 01 0000 0000004C PICTA
01 01 0000 00000054 NOTPOINT
01 01 0000 0000005C IOP
01 01 0000 00000064 MADREAD
01 01 0000 0000006C ENDIOP
01 01 0000 00000074 FORMAT
01 01 0000 0000007C MADWRITE
01 01 0000 00000084 PICTUREN
01 01 0000 00000088 M2
01 01 0000 0000008C M1
01 01 0000 00000090 M
01 01 0000 00000094 QQ2
01 01 0000 00000098 COMMAND
01 01 0000 0000009C QQ1
01 01 0000 000000A0 'ENDSTATEMENT'
01 01 0000 000000A4 Y
01 01 0000 000000A8 X
01 01 0000 000000AC 'SAMEAS'
01 01 0000 00000080 HEAD
01 01 0000 00000084 DISPLAYN
01 01 0000 00000088 SKETCH
01 01 0000 0000029C "' ILLEGAL COMMAND'*"
01 01 0000 000002AF "'    .',10('    .')*"
01 01 0000 000002C3 "."
01 01 0000 000002C4 "13,52C1.1*"
01 01 0000 000002CE "'1   .',10('    .')*"
01 01 0000 000002E2 "*"
01 01 0000 000002E3 " "
01 01 0000 000002E4 "' NOTHING TO DISPLAY.'*"
01 01 0000 000002FB "DISP"
01 01 0000 000002FF "3I*"
01 01 0000 00000302 "' ENTER DISPLAY NUMBER OF POINT AND NEW X,Y'*"
```

```
01 01 0000 0000032F "MOVE"
01 01 0000 00000333 "I*"
01 01 0000 00000335 "' TOO MANY PICTURES.'*"
01 01 0000 0000034C 100
01 01 0000 00000350 "' ENTER DISPLAY NUMBERS FOR ALL POINTS.'*"
01 01 0000 00000379 "PICT"
01 01 0000 0000037D "' THESE ARE NOT POINTS.'*"
01 01 0000 00000396 "' ENTER DISPLAY NUMBERS FOR END-POINTS:'*"
01 01 0000 000003BF "LINE"
01 01 0000 000003C3 "' POINT IS OUTSIDE RASTER RANGE.'*"
01 01 0000 000003E5 "' ASSIGNED DISPLAY NUMBER',HI4*"
01 01 0000 000004C4 50
01 01 0000 000004C8 "2I*"
01 01 0000 00000408 "' ENTER X AND Y COORDINATES:'*"
01 01 0000 00000429 "POIN"
01 01 0000 0000042D "C4,4*"
01 01 0000 00000432 "'0ENTER A COMMAND PLEASE.'*"
01 01 0000 00000450 6
01 01 0000 00000454 5
01 01 0000 00000458 4
01 01 0000 0000045C 3
01 01 0000 00000460 0
01 01 0000 00000464 2
01 01 0000 00000468 1
01 01 0000 00000470 %DIMC002
01 01 0000 000004E0 %DIMC001
01 01 0000 00000498 PICTURE
01 01 0000 00000628 DISPLAY
```

```
DICTIONARY


%DIM0001 'FIXEDARRAY'  01010000 00000480
    COMP.SIZE=4
  COMPONENT= 'INTEGER'
%DIM0002 'FIXEDARRAY'  01010000 00000470
    COMP.SIZE=4
  COMPONENT= 'INTEGER'
'ENDSTATEMENT' 'INTEGER'  01010000 000000AC
'SAMEAS' 'INTEGER'  01010000 000000AC
A 'INTEGERSHORT'  00030034 00000000 (FORMAL PAR)
B 'INTEGERSHORT'  00030030 00000000 (FORMAL PAR)
COMMAND 'CHARACTER'  01010000 00000098
    LENGTH=4
DIS 'INTEGER'  01010000 00000048
DISPA 'ENTRYNAME'  01010000 00000028
  RESULT= 'INTEGER'
DISPLAY 'FIXEDARRAY'  01010000 00000628
    COMP.SIZE=1 DIM.VEC.=%DIM0001
  COMPONENT= 'CHARACTER'
    LENGTH=1
DISPLAYN 'INTEGERSHORT'  01010000 00000084
DX 'INTEGER'  01010000 00000044
DY 'INTEGER'  01010000 00000040
ENDIOP 'ENTRYNAME'  01010000 00000060 'EXTERNAL'
  RESULT= 'INTEGER'
FORMAT 'ENTRYNAME'  01010000 00000074 'EXTERNAL'
  RESULT= 'INTEGER'
HEAD 'POINTER'  01010000 00000080
I 'INTEGER'  01010000 00000034
IOP 'ENTRYNAME'  01010000 0000005C 'EXTERNAL'
  RESULT= 'INTEGER'
J 'INTEGER'  01010000 00000030
LINE 'COMPONENTSTRUCTURE'  0007001C 00000000 'BASED'
    SIZE=20
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
M 'FLOATING'  01010000 00000090
MADREAD 'ENTRYNAME'  01010000 00000064 'EXTERNAL'
  RESULT= 'INTEGER'
MADWRITE 'ENTRYNAME'  01010000 0000007C 'EXTERNAL'
  RESULT= 'INTEGER'
MAX 'ENTRYNAME'  01010000 00000008
  RESULT= 'INTEGER'
MIN 'ENTRYNAME'  01010000 00000014
  RESULT= 'INTEGER'
MOVEA 'ENTRYNAME'  01010000 00000038
  RESULT= 'INTEGER'
M1 'FLOATING'  01010000 00000080
M2 'FLOATING'  01010000 00000088
NOTPOINT 'ENTRYNAME'  01010000 00000054
  RESULT= 'INTEGER'
PICTA 'ENTRYNAME'  01010000 0000004C
  RESULT= 'INTEGER'
PICTURE 'FIXEDARRAY'  01010000 00000498
```

```
    COMP.SIZE=4 DIM.VEC.=%DIM0002
  COMPONENT= 'POINTER'
PICTUREN 'INTEGER'  01C10C00 00000C84
POINT 'COMPONENTSTRUCTURE'  0007002C 00000C00 'BASED'
    SIZE=16
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
P1 'COMPONENTSTRUCTURE'  00070018 C0C0000C 'BASED'
    SIZE=16
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
P2 'COMPONENTSTRUCTURE'  00070014 00000000 'BASED'
    SIZE=16
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
P3 'COMPONENTSTRUCTURE'  00070010 C0CC0000 'BASED'
    SIZE=16
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
QQSV 'COMPONENTSTRUCTURE'  00070024 00000000 'BASED'
    SIZE=16
  COMPONENT= 'POINTER'
  COMPONENT= 'POINTER'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
  COMPONENT= 'INTEGERSHORT'
QQ1 'POINTER'  01C10C00 0C000090
QQ2 'POINTER'  01010000 CCC00094
Q1 'INTEGER'  01010000 CCC00024
Q2 'INTEGER'  01C10000 00C00020
SKETCH 'ENTRYNAME'  01010CC0 0C000088 'ACCESSIBLE'
  RESULT= 'INTEGER'
X 'INTEGER'  01C1CC00 CCC000A8
X 'INTEGERSHORT'  00030C2C 00000000 (FORMAL PAR)
X1 'INTEGER'  01C10000 0C00001C
X2 'INTEGER'  01C10000 CCCC0010
Y 'INTEGER'  01010000 C0C0C0A4
Y 'INTEGERSHORT'  0C03C02E 00CCC000 (FORMAL PAR)
Y1 'INTEGER'  01C10000 C0000004
Y2 'INTEGER'  01C10JCC CCCC0000
" " 'CHARACTER'  C1010CCC 000002E3
    LENGTH=1
"." 'CHARACTER'  C1C100C0 C000C2C3
```

```
    LENGTH=1
"*" 'CHARACTER'  C1010CCC C00002E2
    LENGTH=1
"'     .',10('     .')*" 'CHARACTER'  01010000 000002AF
    LENGTH=2C
"' ASSIGNED DISPLAY NUMBER',HI4*" 'CHARACTER'  01C10000 C00C03E5
    LENGTH=31
"' ENTER DISPLAY NUMBER CF POINT AND NEW X,Y'*" 'CHARACTER'  01010000 00000302
    LENGTH=45
"' ENTER DISPLAY NUMBERS FCR ALL PCINTS.'*" 'CHARACTER'  01010000 00000350
    LENGTH=41
"' ENTER DISPLAY NUMBERS FCR END-PCINTS:'*" 'CHARACTER'  01C10CC0 00000396
    LENGTH=41
"' ENTER X AND Y COORDINATES:'*" 'CHARACTER'  01C10000 CC0CC40B
    LENGTH=30
"' ILLEGAL COMMAND'*" 'CHARACTER'  C1C100CC 00C0029C
    LENGTH=19
"' NOTHING TO DISPLAY.'*" 'CHARACTER'  01C10000 000002E4
    LENGTH=23
"' PUINT IS OUTSIDE RASTER RANGE.'*" 'CHARACTER'  01010CC0 0000C3C3
    LENGTH=34
"' THOSE ARE NOT PUINTS.'*" 'CHARACTER'  01010CCC C000C37D
    LENGTH=25
"' TCC MANY PICTURES.'*" 'CHARACTER'  01C1CCCC 00000335
    LENGTH=22
"'0ENTER A COMMAND PLEASE.'*" 'CHARACTER'  01010000 00000432
    LENGTH=27
"'1    .',10('     .')*" 'CHARACTER'  01010CCC CC00C2CE
    LENGTH=20
"C4.4*" 'CHARACTER'  01C1CC00 0C000420
    LENGTH=5
"DISP" 'CHARACTER'  01C10CC0 000002FB
    LENGTH=4
"I*" 'CHARACTER'  01010CCC 00000333
    LENGTH=2
"I3,52C1.1*" 'CHARACTER'  C1010000 C00002C4
    LENGTH=1C
"LINE" 'CHARACTER'  01010CC0 CCC0038F
    LENGTH=4
"MCVE" 'CHARACTER'  C1C10CC0 00C0032F
    LENGTH=4
"PICT" 'CHARACTER'  01010000 C0C00379
    LENGTH=4
"POIN" 'CHARACTER'  01010000 00000429
    LENGTH=4
"2I*" 'CHARACTER'  01010CCC 00000408
    LENGTH=3
"3I*" 'CHARACTER'  0101CCCC 000002FF
    LENGTH=3
0 'INTEGER'  01010000 CCC00460
1 'INTEGER'  01010000 C0C00468
100 'INTEGER'  C1C1000C C0000340
2 'INTEGER'  01010000 CC0C0464
3 'INTEGER'  C1010000 0C0C045C
4 'INTEGER'  01010000 C0C0C458
5 'INTEGER'  01010000 C0C00454
50 'INTEGER'  01C10000 CC000404
6 'INTEGER'  01C10000 0C0C0450
```

```
EXTERNAL SYMBOL DICTIONARY (SYMBOL,TYPE,ID,ADDR,LENGTH/LDID)

##SKETCH PD 01 000000 00124C
#SKETCH  SD 02 000C00 0C16BA
MADSTACK ER 03
SKETCH   LD    000000 (0C002
MACWRITE ER 04
FORMAT   ER 05
ENDIOP   ER 06
MACREAD  ER 07
IOP      ER 08
GETSPACE ER 09
LINSUB   ER 0A
```

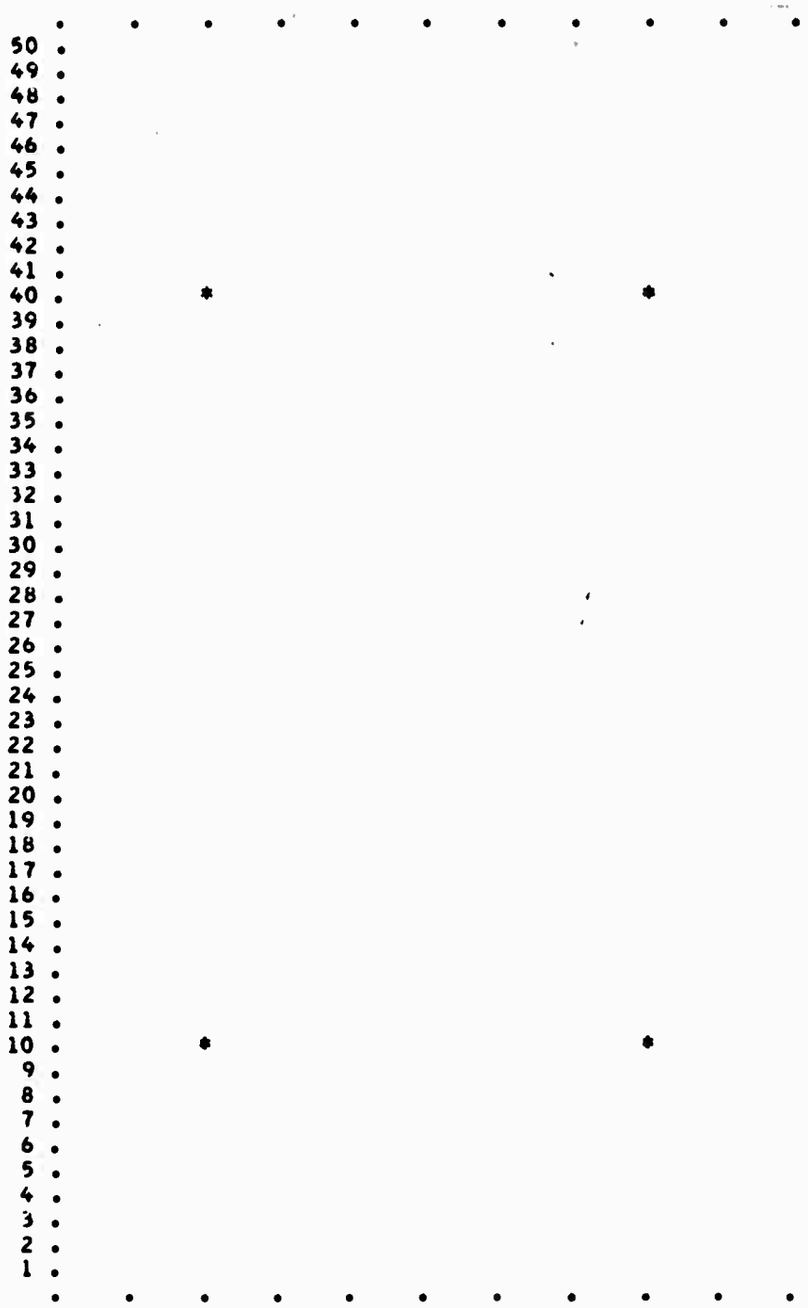
RELOCATION DICTIONARY (P.ID,R.ID,FLAGS,ADDRESS)

```
01  C2  0C  000088
01  04  1C  00007C
01  C5  1C  000074
01  01  0C  000294
01  C6  1C  00006C
01  07  1C  000064
01  01  0C  000288
01  C8  1C  00005C
01  C1  0C  00027C
01  C1  0C  000270
01  C1  0C  000264
01  C1  0C  000258
01  C1  0C  00024C
01  C9  1C  001060
01  C1  0C  000240
01  C1  0C  000228
01  C1  0C  00021C
01  C1  0C  000210
01  C1  0C  000204
01  C1  0C  0001F8
01  C2  0C  000054
01  C1  0C  0001EC
01  C1  0C  0001E0
01  C1  0C  0001D4
01  CA  1C  0010A4
01  C1  0C  001094
01  01  0C  001058
01  C2  0C  00004C
01  C1  0C  0001C8
01  01  0C  0001BC
01  C1  0C  001088
01  C1  0C  00108C
01  C1  0C  0010D4
01  C1  0C  0010D8
01  C1  0C  0001B0
01  C1  0C  0001A4
01  C1  0C  000198
01  C1  0C  00018C
01  C1  0C  000180
01  C2  0C  000038
01  C1  0C  000174
01  C1  0C  00110C
01  C1  0C  001110
01  C1  0C  001114
01  C2  0C  000028
01  C1  0C  001130
01  C1  0C  001134
01  C1  0C  001138
01  C1  0C  00116C
01  01  0C  001164
01  C1  0C  001168
01  C1  0C  00119C
01  C1  0C  0011A0
01  C1  0C  0011A4
01  C1  0C  000118
01  C1  0C  0001CC
01  C1  0C  0001D0
01  C1  0C  0000F4
```

```
01  C1  0C  0000E8
01  C1  0C  0011BC
01  C1  0C  0011C0
01  C1  0C  0011C4
01  C1  0C  0011D8
01  C1  0C  0011DC
01  C1  0C  0011E0
01  C1  0C  0000D0
01  C1  0C  0000C4
01  C2  0C  000014
01  C2  0C  0000C8
02  C1  0C  001648
02  C1  0C  001584
02  C1  0C  000020
01  C1  0C  0011F0
01  C1  0C  0011F4
01  C2  0C  0011F8
01  C3  0C  0011FC
01  C4  0C  001228
01  C5  0C  00122C
01  C6  0C  001230
01  C7  0C  001234
01  C8  0C  001238
01  C1  0C  00123C
01  C9  0C  001240
01  CA  0C  001244
01  C2  0C  001248
02 COCOOO                                   END   SKETCH

      MAD/I COMPILER TIMINGS:               171.625 CPU SECONDS.
                                            326.063 ELAPSED SECONDS.

EXECUTION TERMINATED
```

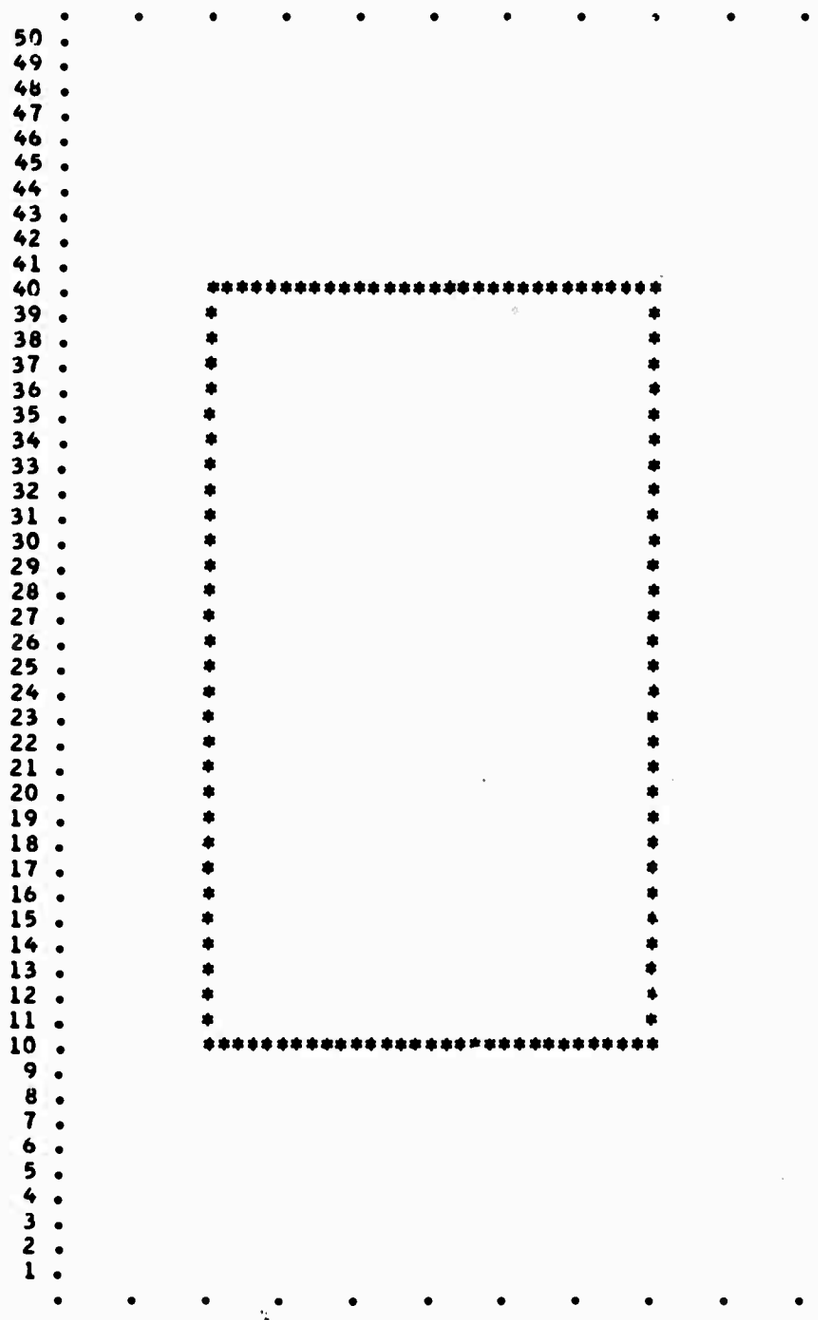
Appendix F. Run of the MAD/I Program

```
$SET ERRORDUMP=ON
$RUN SKETCHOBJ MAP SCARDS=-DATA

 ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ...

 ENTRY = 10C000  SIZE = 00A6B3

NAME      VALUE  T RF     NAME      VALUE  T RF     NAME      VALUE  T RF

GETSPACE 011610 *        FREESPAC 0118A2 *        SYSTEM   0167A4 *
ERROR    0167CE *        PGNTTRP  018E8C *        LOAD     018EF2 *
GETFD    0197E0 *        SCARDS   019A80 *        SPRINT   019A92 *
SPUNCH   019AA4 *        SERCOM   019AB6 *        READ     019B34 *
WRITE    019B50 *        LCSYMBOL 01A5E8 *        GLAP     1030C8  0FFA60
LINSUB   103848  103848 MADIO    103C70  103C70 MADREAD  103C7C
MADWRITE 103C9E          FORMAT   103DBA          IOP      103DFC
ENDIOP   103E42          ##SKETCH 10A00C  10A000 IOPKG    108250  108250
ROPEN    10831E          RCLOSE   108398          POPEN    1083C4
PCLOSE   108410          MDIOPSCT 108D50  1089E8 SPIE     108DE8  108DE8
#SKETCH  10C000  10C000 IOH360   111000  111000 IOHIN    1110F0
IOHOUT   111114          ICHETC   111836          ONE@ATIM 11192C
IOHERP   115000  110F18 MADSTACK 117000  117000

 ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ...

EXECUTION BEGINS

ENTER A COMMAND PLEASE.
NOTHING TO DISPLAY.

ENTER A COMMAND PLEASE.
ENTER X AND Y COORDINATES:
ASSIGNED DISPLAY NUMBER   1

ENTER A COMMAND PLEASE.
ENTER X AND Y COORDINATES:
ASSIGNED DISPLAY NUMBER   2

ENTER A COMMAND PLEASE.
ENTER X AND Y COORDINATES:
ASSIGNED DISPLAY NUMBER   3

ENTER A COMMAND PLEASE.
ENTER X AND Y COORDINATES:
ASSIGNED DISPLAY NUMBER   4

ENTER A COMMAND PLEASE.
```

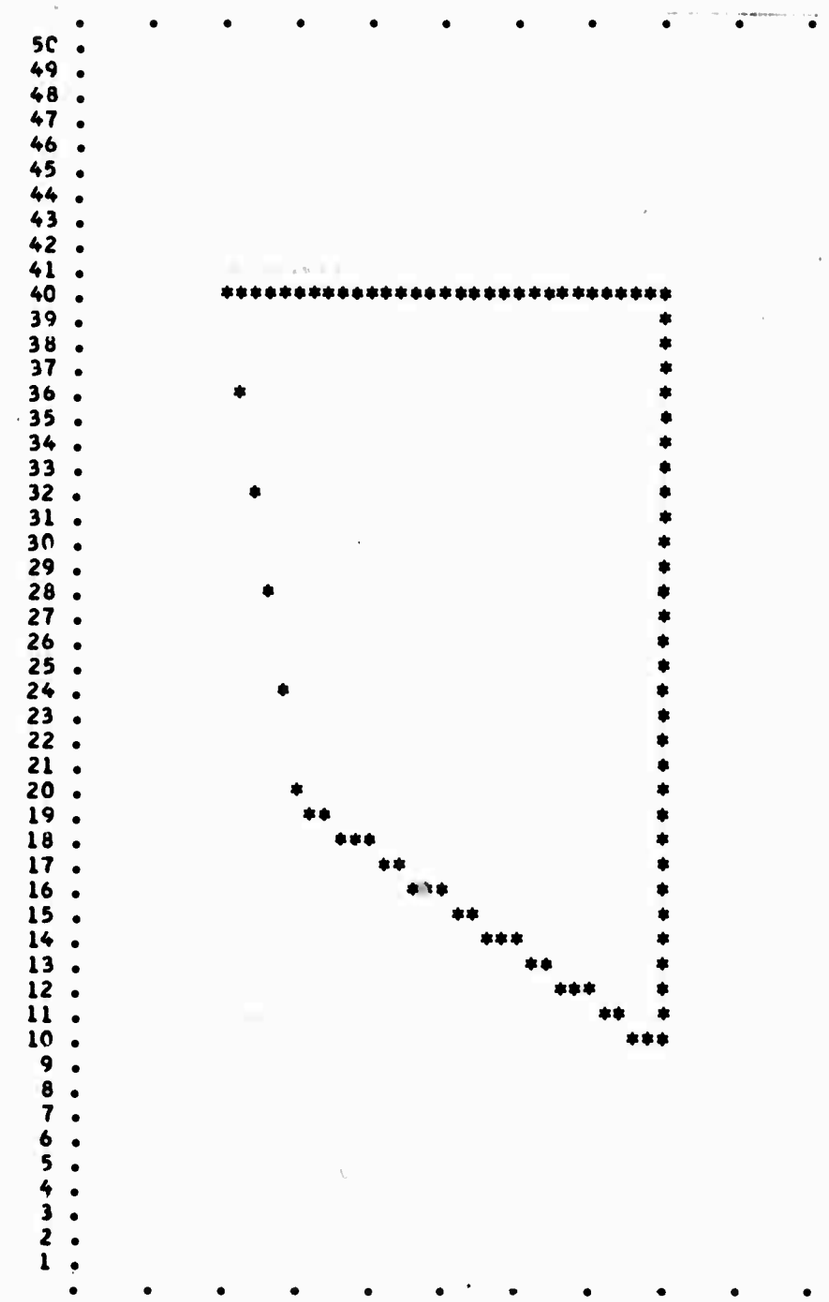


```
ENTER A COMMAND PLEASE.
ENTER DISPLAY NUMBERS FOR END-POINTS:

ENTER A COMMAND PLEASE.
ENTER DISPLAY NUMBERS FOR END-POINTS:

ENTER A COMMAND PLEASE.
```

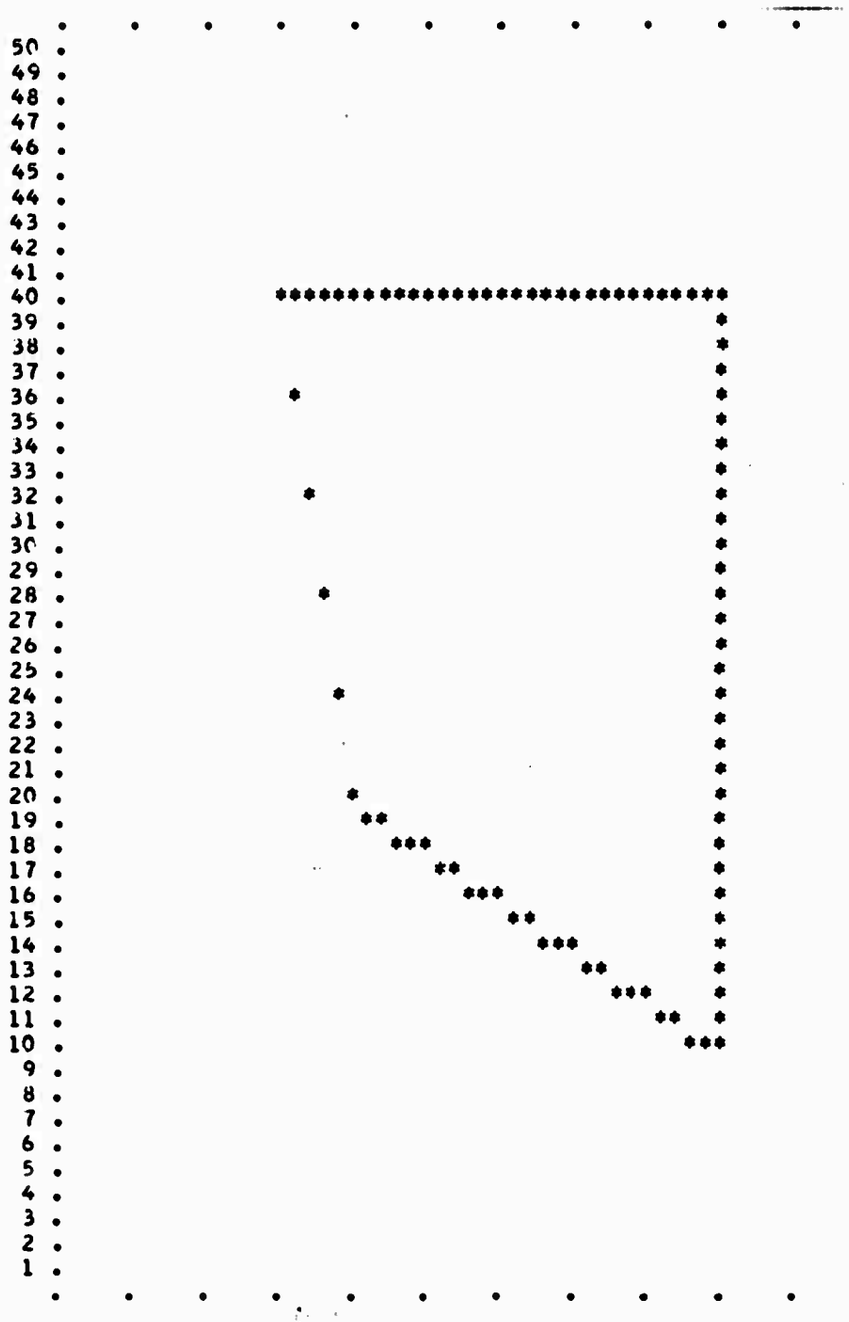
```
ENTER DISPLAY NUMBERS FOR END-POINTS:

ENTER A COMMAND PLEASE.
ENTER DISPLAY NUMBERS FOR END-POINTS:

ENTER A COMMAND PLEASE.
```



```
ENTER A COMMAND PLEASE.
ENTER DISPLAY NUMBER OF POINT AND NEW X,Y

ENTER A COMMAND PLEASE.
```



```
ENTER A COMMAND PLEASE.
ENTER DISPLAY NUMBERS FOR ALL POINTS.

ENTER A COMMAND PLEASE.
ENTER DISPLAY NUMBER OF POINT AND NEW X,Y

ENTER A COMMAND PLEASE.
```



```
ENTER A COMMAND PLEASE.

**** ALL INPUT DATA HAS BEEN PROCESSED - AT LOCATION 1C3DE8
EXECUTION TERMINATED
```

UNCLASSIFIED

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13. ABSTRACT

The MAD/I language is a procedure-oriented algebraic language which is a descendant of ALGOL 60 and 7090 MAD, similar in power and scope to PL/I. The MAD/I compiler is implemented using the MAD/I facility, a flexible translator-building system whose dynamic nature allows compilers to be extended during the compilation process. This paper demonstrates the extension of MAD/I to include several graphics-oriented statements and operators through a lucid example.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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MAD/I						
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Extensible Language						
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Operator Definitions						

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